QUALITY ASSURANCE PROJECT PLAN

FOR RAINFALL-RUNOFF SIMULATION USING

THE HYDROLOGICAL SIMULATION PROGRAM-FORTRAN (HSPF)

FOR THE PROPOSED CRANDON MINE AREA

CRANDON, WISCONSIN

Prepared and compiled by the
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TABLE OF CONTENTS

I. PROJECT DESCRIPTION

Introduction

The Crandon Mining Company (CMC) has proposed a zinc and copper mine just south of Crandon in northern Wisconsin. The company has just been renamed the Nicolet Minerals Company (NMC) as of February, 1998, and will be referred to as such in the remainder of this document. The company is currently in the permitting process with the Wisconsin Department of Natural Resources (WDNR) and has submitted an Environmental Impact Report (EIR) to the WDNR and the U. S. Army Corps of Engineers (COE), because the proposed location of the mine will alter or impact nearby wetlands, requiring federal permits as well as state. The WDNR and the COE will each produce a separate and independent Environmental Impact Statement (EIS). As a reviewing agency for the EIR, and subsequent state and federal EIS's, the U. S. Environmental Protection Agency (USEPA) will apply a hydrology and hydraulic (H&H) model, Hydrological Simulation Program - Fortran (HSPF), to qualitatively and quantitatively evaluate the impact of the mine on the area. The model has been used extensively by the U. S. Geological Survey (USGS), USEPA, and various state and local agencies to simulate storm-water impacts, solute transport, and watershed-management plans. An Interagency Agreement has been initiated between the USEPA, the USGS in Wisconsin and Illinois. The USGS has, through a subcontract, acquired the services of Aqua Terra Consultants (who maintain the model for the USGS and the USEPA), to develop and evaluate a HSPF model suitable for simulation of changes in runoff resulting from mine construction, operation, and closure. The HSPF model will be used to complement the impact analysis for the water budget done on the basis of the MODFLOW ground-water model developed by NMC and WDNR and described in the EIR. The COE also is developing a FEMWATER (Finite Element Mesh for ground-water) to evaluate the mining impacts on the wetlands and surrounding surface water bodies. The results of the FEMWATER model also will provide some input to the HSPF model developed. The results and interpretations from the HSPF model will be available to the WDNR and COE for use in their respective EIS's as they determine is necessary, and available for Tribal use.

The models in use by NMC and the COE focus on estimating the changes in flows to surface-water bodies resulting from changes in the ground-water flows and levels, but do not directly account for the entire surface-water balance for seasons or critical months of the year. The processes of runoff, snowmelt, evapotranspiration, interception, interflow, and erosion, and the changes in these processes due to construction, operation, and closure of the mine are not simulated in the ground-water flow models. Simulation of these processes are critical to a more complete understanding of the effects of mining and to address unique issues in the area potentially affected by the mine. The changes in groundwater are expected to be quite extensive due to the flow of large volumes of ground water into the mine during mine operations and the subsequent dewatering of the mine. Given the seriousness of the potential impacts on such a geologically and hydrologically complex area, the entire hydrologic cycle will be simulated with HSPF with an emphasis on the surface waters, the water budget, and fluctuations of the water budget. The changes in runoff and water levels resulting from mine construction, operation, and closure obtained from HSPF simulation will then be related to the risk to habitat.

Changes in solute and sediment transport resulting from mine construction, operation, and closure also are important to the permitting process and the EIR review. These changes can be simulated in HSPF, however, determination of appropriate model parameters for simulating the solute- and sediment-transport processes on the basis of limited data are complex and are deferred to a possible second phase of the HSPF modeling project.

Potential impacts from the proposed Crandon Mine to the specific watersheds composing the headwaters of the pristine Wolf River, (designated as a State Outstanding Resource Water) as shown in Figure 1, and surrounding the proposed Crandon Mine project site are of obvious major concern to all parties involved in the permitting of the mine as well as to residents in the area, including four tribes of Native Americans: the Sokaogon Chippewa Community Mole Lake Band, the Forest County Potawatomi Community, the Menominee Indian Tribe of Wisconsin, and the Stockbridge-Munsee Band of the Mohican Indians.

Site Description

The proposed mine is in a sulfide ore deposit located approximately 300-350 feet below land surface. The deposit is 2,200 feet beneath the ground at its deepest point, 100-feet wide, and nearly 1-mile long. This deposit will be mined primarily for zinc and copper. These minerals were deposited as ocean floor volcanics that were later metamorphosed and tilted to a nearly vertical position. The bedrock is composed of metamorphosed igneous rocks. The surface rock is composed of glacial till and outwash, with a hummocky, forested land surface and many lakes and wetlands. Due to the depth of the proposed mine, about 860,000 gallons per day of ground-water will be pumped from the mine area, treated, and discharged out of the upper Wolf River watershed. The ground-water pumpage will result in drawdown of the potentiometric surface and (or) water table, which may affect the watersheds surrounding the mine site. Because all the aquatic resources in the upper Wolf River watershed are designated by the WDNR as fully usable, the potential of any permanent damage to those designations must be considered significant due to the rarity of such undeveloped watersheds. Other site-related activities, such as the clear cutting of trees for buildings and tailings management, building access roads and rail spur lines, increasing housing and buildings, potentially changing drainage patterns and surface water flows, may combine with the effects of drawdown of the potentiometric surface and (or) water table and may decrease or increase the effects on the ecosystem of the drawdown alone.

Regulatory Site History and Considerations

The Crandon Mining Company began researching the potential for development in this area in the 1970's and 1980's. In 1994, the CMC issued a Notice of Intent with a Detailed Scope of Study (NOI/SOS) to the WDNR for mining the deposit. The current WDNR timetable for potential permit issuance is in late 1999.

Environmental Justice - The area must be evaluated within the context of Executive Order 12898, Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations and as outlined in the draft Guidance for Incorporating Environmental Justice Concerns.

National Environmental Policy Act (NEPA) - In the USEPA's NEPA Compliance Analysis, the USEPA will use the data and evaluations obtained from the H&H model to help determine direct and indirect effects of the proposed mine on the ecosystem. Also, the data and evaluations will be used to help determine if any portion of the population is affected more than others, such as whether tribal cultural resources bear more of an impact from the mine than resources of value to other ethnic groups or populations in the area. Other criteria under NEPA are unique characteristics, such as the close proximity to the Native American tribal reservations and the cultural resources associated with the tribes, as well as the nearness of the Wolf River, the Nicolet National Forest, and the Highland Legion State Forest. In addition, Federal agencies (such as USEPA) have statutory Federal Trust Responsibilities to the four federally-recognized Native American tribes to determine how this proposed mine may affect their culture and environment. The USEPA also will insure that environmental information is available to public officials, citizens, and the COE before decisions are made and actions are taken, as stated in requirements in several regulations and statutes of the NEPA. In this project, however, the USEPA is a reviewing agency and not the lead so some of these issues may be addressed by the COE. The USEPA believes the available data and evaluation do not adequately address the issues of water-level and water-budget changes resulting from mine construction, operation, and closure which can affect the habitat and ecosystems of the area. The greatest impacts to the water budget are considered, at this point, to be the drawdown of the potentiometric surface and (or) water table as the ground-water is pumped during mining operations and the change in land surface due to construction of the mine, the tailings-management area (TMA), and supporting facilities. The outputs from the HSPF model will be verified by the modelers and then evaluated by biologists and ecologists to address the habitat and ecosystem issues and the impact on terrestrial and aquatic life. A description of the issues and possible impacts will be available to the WDNR and COE as part of their permitting, EIR review process, and EIS preparation, respectively.

Project Data-Quality Objectives

The description of the Project Data-Quality Objectives (PDQO's) is the key component of a Quality Assurance Project Plan, and includes the following seven steps.
1) Stating the problem to be studied.
2) Identifying the decision that will be made using the environmental data from the study and actions that will result to solve the problem.
3) Identifying the information and measurements needed to make the decisions.
4) Specifying the boundaries (area and time period) to which the decisions apply.
5) Specifying how the environmental data will be summarized and used to make the decision.
6) Specifying acceptable error rates considering the consequences of making an incorrect decision.
7) Selecting the most resource-efficient study design that will achieve all of the PDQO's.

For each of the decisions to be made or questions to be answered, steps1-6 will be discussed in detail. Once each PDQO has been discussed, then step 7 will be discussed in detail as a closing summary on how the proposed project will support the PDQO's.

With respect to the potential effects of the proposed mine on the surrounding areas, 11 questions have been developed with respect to topics of surface-water level, runoff, and chemistry; erosion; and ground-water and surface-water interaction as follows.

<u>1. Surface-water levels, runoff, and chemistry</u>

a) Which surface-water bodies (lakes, creeks, wetlands) strongly interact with ground water and, thus, can be substantially affected by ground-water pumpage from the mine?
b) Will the changes in runoff and water levels resulting from mine construction, operation, and closure impair the growth of wild rice?
c) Will the changes in runoff and water levels resulting from mine construction, operation, and closure impair the health of other flora, fauna, and habitat?
d) Will the changes in runoff and water levels resulting from mine construction, operation, and closure substantially impact the culture or cultural resources of the various Native American Tribes in the vicinity of the proposed mine (with a particular focus on the Mole Lake Reservation)?
e) Will mine construction, operation, and closure substantially alter the frequency and intensity of flooding downstream from the mine site?
f) Will the surface-water chemistry of the water bodies affected by changes in runoff quality from the mine site change such that their use designation changes from "full use?"

<u>2. Erosion</u>

a) Will the changes in the rate of sedimentation in the water bodies affected by runoff from the mine site resulting from mine construction, operation, and closure be sufficient to impair the habitat functions of these water bodies?
b) Will the changes in the transport of heavy metals adsorbed to sediment particles or by air deposition and their subsequent fate in the water bodies affected by mine construction, operation, and closure be sufficient to impair the habitat functions of these water bodies?

<u>3. Ground-water and surface-water interaction</u>

a) How quickly do surface-water levels in the water bodies potentially affected by runoff from the mine site respond to storm runoff, outflow from ground-water storage, and ground-water pumping at the mine site?
b) Do ground-water levels, flow directions, and flow rates change substantially as a result of mine construction, operation, and closure?
c) Does ground-water chemistry change substantially as a result of mine construction, operation, and closure? In particular, what are the changes in ground-water and surface-water chemistry resulting from potential subsurface and surface acid mine drainage?

Only questions 1(a-e) will be directly addressed in the HSPF modeling effort done for this project. Sediment-transport and water-chemistry processes can be simulated with the HSPF model, and, thus, information related to questions 1(f) and 2(a-b) may be obtained. However, simulation of sediment transport and water chemistry with HSPF will be deferred to a possible second phase of the HSPF modeling effort. At this time, the project team feels that complete attention should be dedicated to developing a reliable simulation model for determining the water budget in the vicinity of the proposed Crandon Mine and changes to this budget as a result of mine construction, operation, and closure. Including simulation of sediment transport and water chemistry could delay the prompt development of a reliable HSPF model for water-budget simulation. Further, reliable simulation of the water budget must be accomplished as the foundation for possible future simulation of sediment transport and water chemistry.

The HSPF modeling effort done for this project will provide supporting information with respect to questions 3(a-c) related to ground-water and surface-water interaction. The primary information for answering questions 3(a-c) will be obtained from the MODFLOW model developed by the NMC and WDNR, the Solute Transport Model developed by NMC, and the FEMWATER model developed by the COE. Ground-water levels, flow directions, and flow rates are simulated in the MODFLOW and FEMWATER models on the basis of measured and computed aquifer properties, assumed or measured boundary conditions, measured water levels in observation wells, measured streamflow during base-flow conditions, input of known pumpage rates, and assumed recharge rates from surface-soil layers. Only a limited range of assumed recharge rates will result in a valid simulation of measured water levels in observation wells. The HSPF model simulates the surface water balance with an input of precipitation, potential evapotranspiration, and meteorologic conditions, and outputs of actual evapotranspiration, streamflow (the sum of surface runoff, interflow (prompt subsurface flow), and base flow from ground water), and percolation to deep aquifers that do not contribute to the local surface streams. This water-balance simulation also will be valid only for a limited range of values for recharge to ground water. By comparing the valid ranges of values for recharge in HSPF to those for MODFLOW and (or) FEMWATER, the models can be used jointly to determine a recharge rate that yields reliable simulation of the surface-water budget and ground-water levels and flow rates.

The PDQO's that will be answered in detail through this HSPF modeling effort are described in detail in the following subsections.

The items underlined in the following PDQO descriptions must be specified by 1(a) hydrologists familiar with lake-level fluctuations in northern Wisconsin, 1(b) biologists familiar with the growth of wild rice, 1(c) biologists familiar with the flora, fauna, and habitat of interest, and 1(e) hydrologists familiar with surface water flow in northern Wisconsin.

1(a) Identification of Surface-Water Bodies that Strongly Interact with Ground Water

Problem: According to the EIR prepared by the NMC, a number of the lakes and ponds in the vicinity of the proposed Crandon Mine are poorly connected to the primary aquifer and, thus, would be minimally affected by drawdown resulting from mine operations. Oak Lake is described as a "perched lake" with a silty clay lake bed above the water table through which little water percolates. Thus, the level of this lake is considered to be independent of the level of the primary aquifer. Duck, Deep Hole, Skunk, and Little Sand Lakes are described as "ground-water-head-dependent" lakes. The water levels in these lakes are affected by the ground-water levels. However, the lake beds limit percolation to the aquifer, maintaining a higher water level in the lakes than the surrounding water table.
The water budget for a lake in HSPF is modeled as

$$\Delta S = P + I + GW - E - O,$$

where P is the precipitation directly onto the lake, I is the surface and subsurface inflow from tributary areas and streams, GW is the deep ground-water inflow or outflow (which would have a negative value), E is evaporation from the lake surface, and O is surface outflow to a draining stream. The lakes in question are all outside of the Swamp Creek Basin. Thus, the rainfall-runoff relations will already be established (calibrated) to the streamgage record in the Swamp Creek Basin establishing regional characteristic values for I and E. In the proposed approach, the deep GW term (i.e. subsurface interactions not included in HSPF) will be omitted initially from the water-budget equation. Each of the remaining terms in the water-budget equation is constrained as follows: P is a measured value, the values of I and E are determined from calibration on Swamp Creek, and the range of O is limited by the requirement to properly simulate the water budget of the water bodies receiving water from the lake in question and by the hydraulics of the lake outlet. Thus, if the observed variation in lake levels cannot be reasonably simulated omitting the deep ground-water term, then it is likely that ground-water interaction must be simulated for this lake.

These results may not be conclusive because of the uncertainties and errors in HSPF simulation. Also, for the ground-water-head dependent lakes, the head difference between the lake level and the water table may be too small under natural conditions to result in substantial flows from the lakes to ground water. However, when the water table drops as a result of mining, the head difference could become large enough to result in substantial flows from the lakes to ground water. This issue cannot be evaluated because the available lake-level data do not reflect the effects of a substantially lower water table.

Decision: Are the lakes listed previously sufficiently affected by ground-water level fluctuations that lake levels and the overall water budget cannot be reliably simulated without considering ground-water interactions in HSPF? If lake levels cannot be simulated without consideration of ground-water interactions, then future large-scale, ground-water drawdown would be expected to have substantial effects on lake levels and water budgets. However, if natural lake levels can be simulated without consideration of ground-water interactions, the effects of future large-scale, ground-water drawdown on lake levels cannot be reliably evaluated because the HSPF model has not been developed and evaluated under such conditions.

Information Needed: A long series of measured monthly lake levels are needed to determine if lake levels can be reliably simulated without considering ground-water interactions when utilizing other model parameters that result in reliable simulation of the water budget throughout the Swamp Creek (a portion of the WDNR's Upper Wolf River and Post Lake Watershed, Figure 2) and Pickerel Creek watersheds (a portion of the WDNR's Lily River Watershed, Figure 3).

Boundaries: The areas to which the decision will apply are Oak, Duck, Deep Hole, Skunk, and Little Sand Lakes. These lakes are shown in Figure 3.1 in the attached Simulation Plan, with HSPF segmentation including portions of the two basins under study. The time period to which this decision will apply is the period of construction, operation, and closure for the proposed Crandon Mine.

Data Summarization: The simulated time series of runoff will be summarized as a series of monthly lake levels that will be compared with the measured series of monthly lake levels. If the average difference between the measured and simulated lake levels (error) is less than or equal to X ft and the maximum error in simulated lake levels is less than or equal to Y ft, then the hypothesis that the lake levels are not dependent on the surrounding ground-water levels is accepted.

Acceptable Error Rates: The acceptable error rate in the decision has been factored into the selection of the simulated lake-level-error tolerances given previously.

1(b) Effect of Runoff Changes on Wild Rice

Problem: Rice Lake holds the largest and densest stand of wild rice on an inland lake in Wisconsin. Wild rice is highly dependent on a limited range of flow velocities, flows, water levels, pH, dissolved organic carbon, metals, nutrients, and sulfate for reproduction and growth. The wild rice is of great cultural and economic value to the Sokaogon Chippewa Community Mole Lake Band. Therefore, changes in hydrology or hydraulics resulting from the construction, operation, and closure of the proposed Crandon Mine must not adversely affect the wild rice. This phase of the HSPF modeling project will focus on runoff simulation and, thus, HSPF simulation will be applied to determine if various phases of the mine development result in velocities and water levels substantially different from natural conditions.

Wild rice seems most susceptible to water-level changes from germination (mid- to late-April) to the beginning of the emergent leaf stage (May to early July). The most obvious damage to the rice is uprooting from the flocculent sediments that can be caused by several processes including increased wave action near the sediment at lower water levels; pulled out by submerged, buoyant leaves during a rapid increase in water levels; and weakened roots because of less light due to higher water levels or turbidity. Uprooting also can occur throughout the growing season (May to mid-September) and the likelihood of uprooting is enhanced by changes in water depth, wind, and metals concentrations.

As previously discussed, growth and survival of wild rice is substantially affected by many factors in addition to flow rates and water levels. For example, increases in metal concentrations retard root growth, thereby increasing the likelihood of uprooting. Also, wild rice over-winters as a seed and may be susceptible to increased sedimentation rates from mid-September to May. Therefore, maintenance of appropriate flow rates and water levels alone will not guarantee the survival of the wild rice if mining activities result in adverse impacts on water quality, sedimentation, and other factors. However, consideration of the effects of changes in flow rates and water levels is a first step toward assessing the survival of the wild rice under changed runoff conditions resulting from mine construction, operation, and closure.

Decision:

- Are water levels in Rice Lake maintained at a range of x inches to x feet in mid- to late-April when the grain begins to **germinate** such that the growth of the wild rice will not be impaired?
- Are water levels in Rice Lake maintained at a range of x inches to x feet during **emergent leaf stage** May to early July**,** and would the frequency of mid-summer flooding not substantially change such that the growth of the wild rice would not be impaired?
- Once the plants are in **midseason**, August to early September, will the frequency of water levels negatively affecting growth substantially increase such that the increase will cause the plants to topple and lodge?
- Once the plants have **completed growth**, mid-September, will the frequency of water levels negatively affecting growth substantially increase such that the increase will batter the stems, tangle the leaves and panicles and damage the seed crop?

If any of these conditions result, the NMC should find a way to maintain natural water levels in Rice Lake.
The items underlined in the above decision must be specified by a biologist familiar with the growth of wild rice.

Information Needed: A long time series (20 years or more) of lake levels corresponding to hypothetical runoff from the Swamp Creek watershed under natural conditions are needed to determine the range in lake levels at key times in the growing season resulting from natural fluctuations in runoff. Long time series of lake levels are needed corresponding to hypothetical runoff from the Swamp Creek watershed under conditions of mine construction, operation, and closure. In each case, the hypothetical runoff time series is generated using identical long-term data series of meteorological conditions (precipitation, temperature, wind, radiation, etc.) collected as close as available to the proposed mine. The hypothetical runoff series for natural and mine conditions will then be compared as discussed in the Data Summarization section.

Boundaries: The area to which this decision will apply is the Swamp Creek watershed up to and including Rice Lake as shown in Figure 3.1 in the Simulation Plan. The time period to which this decision will apply is the period of construction, operation, and closure for the proposed Crandon Mine.

Data Summarization: The simulated long-term time series of runoff for natural and mining conditions will be summarized as frequency distributions of lake levels during the key times of the growing season. The changes in frequency of water levels negatively affecting growth may be determined for mining conditions compared to natural conditions. Also, the magnitude of changes in highest and lowest water level over the simulated period can be compared between the mining and natural conditions for the key times in the growing season. The changes in the frequency of water levels negatively affecting growth and in high and low water levels during the growing season can be compared to the criteria previously given and a decision can be made regarding the magnitude of the effect of mining on wild rice.

Acceptable Error Rates: Because the lake levels will be simulated for a long time period, (20 years or more) and the simulated data will be analyzed utilizing a frequency distribution, the acceptable error rate should be factored into the biological criteria on the unacceptable frequency of stressful water levels.

<u>1c). Will the changes in runoff and water levels resulting from mine construction, operation, and closure impair the health of flora, fauna, and habitat?</u>

Problem: A land and water survey conducted around the proposed mine site (Foth & Van Dyke, 1995) observed a total of five endangered, five threatened, 40 special concern, and one proposed special concern species as listed by the State of Wisconsin. Further, in the project area 36 mammal species, 132 bird species, and 45 butterfly species have been identified. These and numerous other biotic components could be affected by changes in habitat resulting from changes in streamflow, lake levels, and groundwater levels caused by mine construction, operation, and closure. Clearly, it would not be possible to evaluate the potential effects of mining-related operations on all species. Thus, certain key indicator species must be identified whose presence and population robustness indicate the general health of the ecosystem. The U.S. Fish and Wildlife Service (FWS)(1997, written communication) has suggested that for the lakes in the vicinity of the project area potential indicator species include phytoplankton, zooplankton, benthic organisms, submerged aquatic plants, reptiles, amphibians, and fish populations; whereas for streams in the vicinity of the project area potential indicator species include macroinvertebrates (including the benthos), periphyton, and fish populations.

Other Concerns

Other concerns are related to sediment fluctuations, turbidity changes, average temperature increases or decreases, nutrient cycling and storage, and heavy metals. The intent of this study is not to minimize the impact of these influences, but they will not be a focus at this time. The possibility of species invasion may be considered if the relation between species invasion and water levels can be determined from the literature. (e.g. as invasion is established for purple loosestrife)

It is known that if the model predicts decreased water levels, greater **turbidity** can result from exposure to wind which can resuspend **sediment**, or increase erosion from more exposed banks. A shift in the plant community composition may result due to decreasing both the available light and dissolved oxygen. Changes in sediment type or amount could smother eggs.

If the model predicts increases or decreases in average water levels, then the average **temperature** may change with possible consequences of increased evaporation rates, changes in productivity, nutrient cycling, and the amount of dissolved oxygen. The biota could be affected with changing the timing of emerging insects, and the type and growth rates of fish.

If the model predicts significant changes in water levels or stream discharges, basic changes in **nutrient cycling** in wetlands may occur. Changes in plankton production and/or the plant community composition could occur. Drier areas without surface inundation, but with saturated soils, may be the most drastically affected by water-level changes, and may be very important to the overall nutrient dynamics of the system.

Weakened or disturbed plant communities are more susceptible to **invasions** by noxious weeds such as purple loosestrife and Phragmites. The introduction of these plants can have serious and often irreversible consequences to a wetland.

Decision: Are <u>water levels or discharges in selected lakes, streams, or wetlands higher or lower, or the frequency of stressful water levels substantially increased at key times in the life cycle for **selected species**</u> **such that their health or habitat requirements could be impaired** by the change in the physical parameters that comprise aquatic or terrestrial habitats? (This depends on the magnitude of the change in the quantifiable parameters affecting habitat viability resulting from different mining conditions relative to the range of error of the model. Therefore, some biota may be affected by changes in discharge and water level with different degrees of certainty, whereas for other biota the effects of changes in discharge and water levels may not be determined with certainty.)

The items underlined in the above decision must be specified by a biologist familiar with the habitat requirement for selected species and include those in streams, lakes, and wetlands.

Other Related Decisions

If the modeling scenarios indicate a reasonable potential that mine construction, operation, or closure would result in changes in discharge or water levels that adversely impact biota, could actions be taken to prevent these changes or mitigate

their deleterious effects, and **ensure proposed mitigation will not create undesirable secondary impacts?**
Can a **long-term monitoring plan** be developed that integrates **indicator** species and **their habitat** sensitivities to contribute to future decisions?

Information needed: Modeling - A long time series (20 years or more) of lake levels and/or discharges are needed corresponding to hypothetical runoff from the affected watershed under natural conditions to determine the range in lake levels at key times in the growing season resulting from natural fluctuations in runoff. Long time series of lake levels are needed corresponding to hypothetical runoff from the Swamp Creek watershed under conditions of mine construction, operation, and closure. In each case, the hypothetical runoff time series is generated using identical long-term data series of meteorological conditions (precipitation, temperature, wind, radiation, etc.) collected in the vicinity of the proposed mine. The hypothetical runoff series for natural and mine conditions will then be compared.

Taxa - The hydraulic and hydrological results of this modeling project will be applied to biological impact assessment, mitigation measures, and integrated into long-term monitoring. Any of these three objectives (assessment, mitigation, monitoring) may be studied for a selected species or taxa. It is also important to collect sufficient data or have on hand sufficient data to serve as an historic record or baseline to provide insight into expected seasonal and annual variations. In some cases these data are available through other Agencies, including possibly the FWS, the COE, and the WDNR. The taxa will be chosen for lakes, streams, and wetlands habitats, using those species found at the mine site which have already been catalogued by the Nicolet Minerals Company or others, including but not limited to the personal field experience of representatives from the Tribes, the Great Lakes Indian Fish and Wildlife Commission (GLIFWC), the USGS, or the WDNR.

Taxa for which baseline data are gathered should possess characteristics which allow for accomplishment of the objectives of biological assessment, mitigation, and/or monitoring. A number of the suggested criteria are as follows:

- The taxa should be reasonably common, and well distributed within a water body. This will provide some assurance of being able to measure the species in future sampling efforts and would allow for statistically significant sample sizes.
- The taxa should be easily identified, and not likely to be confused with other taxonomic entities.
- The taxa should be known or suspected to be sensitive to distinctive environmental changes which are expected as a result of the Crandon Mine project. This helps ensure that there is a high correlation between change in populations and the express environmental change.

- The taxa should not be expected to exhibit wide fluctuations in abundance, which could make actual population changes difficult to detect.
- The taxa should have a rapid response to change (e.g., periphyton)
- The taxa should be either well enough understood or sufficiently sensitive that thresholds or triggers can be identified.

Candidate Management Indicator Species (MIS) Evaluation

The details of indicator criteria, species background, significant effects, and socioeconomic considerations can be found in the MIS evaluation form from the Forest Service for long-term monitoring and choosing management species. The characteristics used for choosing indicator criteria may include some or all of those listed above and, in addition, whether the species best represents a public issue, concern, or opportunity. The species background is important in selecting management indicators, such as whether it is: Federally-listed as endangered or threatened, Regionally Sensitive, in demand for recreation, for commercial or subsistence use, representative of special habitats, or indicative of trends in other species or conditions of biological communities. Significant effects of management activities that potentially could impact populations are compositional changes (vegetative, faunal, exotics, etc.), structural changes (availability of woody debris, connective linkages, dispersal barriers), functional changes (soil productivity, insect/disease factors, predation, parasitism), hydrologic changes (water temperature, flow, sedimentation), and chemical changes. Socioeconomic considerations may include access conflicts, visual impacts, consumption demands, or effects on animal behavior.

The primary socioeconomic concern to the Tribes and many others in the area are the natural resources of rice, fish, water fowl, and overall health of the waters and the environment. Many of the Tribal economic, cultural, and ceremonial practices are closely associated with these resources. Though these types of impacts cannot directly be interpreted in the modeling analysis, the impacts of the project on the culture of the four Tribes in the area are considered to be one of the greatest potential impacts and will be outlined with relevant references in the Cultural Impacts portion of this document (PDQO 1(d)).

The FWS also recommends selecting reference surface water bodies and wetlands. A reference site acts as a control sample in that the area is chosen for existing conditions that are similar to those found at the proposed mine site. The reference site must have similar characteristics to the current (undeveloped) mine site, such as: population density, geography, geology, vegetation, habitat type, stream type and watershed features. The reference site should be near enough to the mine site to experience similar meteorological conditions and far enough away to be out of the influence of the mine's potential ground-water or surface-water impacts. It is also recognized that there may be legal and practical issues to consider when choosing the reference site.

Boundaries: The area to which decisions will apply consists of the surface water bodies for which the most significant effects on flora, fauna, and habitat from runoff changes resulting from mine construction, operation, and closure are expected. These include Deep Hole, Duck, Little Sand, Oak, Rolling Stone, Rice, Skunk, Ground Hemlock, Hoffman Springs, St. John's, and Walsh Lakes. The streams of concern are Swamp Creek, Pickerel Creek, Hoffman Creek, Hemlock Creek and Creek 12-9 (see Figure 3.1 in the Simulation Plan). The time period to which this decision will apply is the period of construction, operation, and closure for the proposed Crandon Mine and other time periods to be determined thereafter, such as seven generations by Tribal custom or 150 years after closure of the mine.

Data Summarization: The simulated long-term time series of runoff for natural and mining conditions will be summarized as frequency distributions of lake levels, wetland levels, and/or discharges during the key times of the life cycles of the indicator species. The changes in frequency of stressful water levels and/or discharges will be determined for mining conditions compared to natural conditions. The changes in stress frequency and low water levels or discharges can be compared to the biological criteria previously given and a decision regarding the magnitude of the effect of mining on indicator species made.

The linking of the resultant data and the biota will be on several levels after the model is run, including but not necessarily limited to biological impact assessment, possible mitigation assessment, and developing and implementing long-term monitoring. The summarization will be relatively simple and some of the results may be illustrated in tabular format. The lakes, streams, wetlands, reaches, or segments within the watershed will be separated out as needed to better assess the results. The spatial delineations will then be categorized, some from a mapped format, into parameters of interest, such as physical, biological, land cover, or temporal, and can be further subdivided as needed. The physical parameters will include average annual water depth, seasonal maximum water depth, average annual decreases in discharge or water depth, etc. The biological parameters will include the areal extent of, but is not limited only to naming, the land cover. Implicit in the name is the biotic community and habitat it represents, such as wet meadow, shrub swamp, conifer swamp, deciduous swamp, bog, etc., with sensitive species to be further described upon formulation of the monitoring plan. The temporal settings will include reproductive phases, critical developmental phases, or stress times for the biota. Topographic maps and ground water drawdown contour maps may be used in conjunction with biota/land cover maps, segmentation maps, and plant construction plans to analyze the projected changes in the biotic community.

The monitoring plan will include general background and a statement of objectives and philosophy, design mitigation, and uses of information. A geographic setting will include the watershed maps and segmentation; the temporal setting will again reflect the baseline, construction, operation, and closure scenarios. The actual design of the monitoring plan will include reference conditions; the statistical design; logistical considerations; integration of sampling efforts; and endpoints for maximum efficiency, quality control, and analysis. The monitoring endpoints will include the parameters and measurement plans for the physical, chemical, and biological components of the monitoring. A description of the use of the data incorporates many issues, including decision points, determining changes/degree of change, calibrating models, verifying future predictions, planning the mitigation, adjustments to monitoring, maintenance of permit requirements or conditions, and evaluating future permit applications. Finally, the plan will include reporting procedures.

Acceptable Error Rates: Because the lake and wetland levels and discharges will be simulated for a long time period (20 years or more) and simulated data will be analyzed utilizing a frequency distribution, the acceptable error rate should be factored into the biological criteria on the unacceptable frequency of stressful water levels.

<u>1(d) Effect of Runoff Changes on Tribal Cultural Resources</u>

Problem: The construction of the mine facilities will significantly change the land cover of the area from forested to: a plant site, tailings management area, sedimentation ponds, supporting access roads, a railroad spur, housing facilities, etc. Though ground -water and surface-water impacts are currently under study, the modification of the land surface is a major impact from the aspects of changing sedimentation and turbidity in the surface waters and changing the chemistry (trace metals, pH, temperature) and hydrology through changing infiltration amounts and runoff rates to the surface and ground water. Though changes to surface-water flows resulting from the mining impacts may prove to be minimal, these changes coupled with direct and indirect impacts caused by ground-water drawdown and other mining activity-related impacts may cause unacceptable impacts to cultural resources in and around the project area. The greatest socioeconomic and cultural impacts will be on the Tribes on established reservations in the area, including in order from greatest impact to the least, the Sokaogon Chippewa Community Mole Lake Band, the Menominee, the Forest County Potawatomi, and the Stockbridge-Munsee. The greatest impact of any adverse effects from the mining would be to the Mole Lake Band due to their proximity downstream from and directly adjacent to the mine, and because of the historic and current growing and harvesting of wild rice, *Zizania aquatica*, at Rice Lake on the reservation.

Decision: The decision to be made is whether the changes in stream discharge, water levels, or flood/drought frequency and intensity resulting from mine construction, operation, and closure will vary enough from the natural conditions in the watershed to have a deleterious effect on the water resources and related cultural resources such as wild rice, and hence the rice growing and gathering traditions of the people. This does not imply that other aspects of the mine impacts are not acknowledged, but the focus here is on what the model can predict related to hydraulic and hydrological changes that affect the natural environment of the human populations inhabiting the area for hundreds, and for some populations, thousands of years. It has been shown through cultural and historical studies of Native peoples that habitat use produces resources of economic and cultural value. These issues were brought up over a hundred years ago when treaties were being negotiated. The wild rice issue has been an historical focus, not just a recent response to the potential mining impacts.

Information Needed: More information is available than will be discussed for this model. The focus of this study is on the direct impact of the mine to the natural environment of the Tribal peoples, and will not expand to economics, demographics, infrastructure, or other historical mining data.

THE MENOMINEE
The Menominee have been in the area for many years, which may be counted in millennia. Of all the Algonquian speaking groups, the Menominee show the largest continuous residence in one area. The Menominees are currently the largest Tribe in the state of Wisconsin and comprise 25% of the reservation population of the state. There have always been strong cultural ties to hunting and fishing, using the waterways for transportation, with sturgeon being a very important part of their lives and sustenance. The history of the Menominee genesis, which occurred at the mouth of the Menominee River and at Lake Winnebago, includes the Bear clans giving a gift of wild rice and a gift of the river. In the 1600's, it was recorded that the name Menominee, or *Omanominewak* (Wild Rice Men), comes from their word for wild rice, *manoma.* In the 1800's, several treaties stipulated that waters with sturgeon and land with wild rice would be part of the agreement for the establishment of the Menominee reservation. In 1854, the current location near Keshena and Shawano Lake (known for wild rice) was originally established as the area comprising twelve townships lying upon the Wolf River (known breeding ground for the sturgeon). The location of the current reservation is shown in Figure 4, in Menominee County. In the 1900's, several construction projects inhibited the sturgeon population from flourishing but now steps are underway to return lake sturgeon to the reservation. Current concerns about impacts on the reservation are directly related to mining impacts.

THE FOREST COUNTY POTAWATOMI
The Potawatomi have a distinct language within the Algonquin family. Most of their villages were along lakeshores in Wisconsin, with fewer in Michigan, Indiana, and Illinois. The Forest County Potawatomi are descendants of displaced ancestors who were driven west in the early 1800's. In the early 1900's, they received land around

Stone Lake and have remained there ever since. They have not historically been farmers, but primarily hunt, fish, and gather. Therefore, the quality of the air and water are of special concern. Figure 2 shows the reservation location in Forest County.

MOLE LAKE CHIPPEWA
Rice has been a significant part of the Chippewa culture since at least the late 1600's when they migrated south from the southern shore of Lake Superior. Wild rice was used for bartering and for food. In the 1800's it had been recorded that each of the 1,000 families of the Lake Superior bands harvested and utilized the rice. In the 1900's, much was written about the importance of the rice as food, but the harvest was also a time of feasting and dancing. Mole Lake Band members currently rice on their own land and acquire the needed licenses for harvesting on non-reservation property. Recent interviews revealed that some Tribal members have been ricing for over fifty years and know the current rice locations for many area lakes. This resource, furthermore, is not referred to only as a resource, but as having animate properties, along with animals, plants, lakes, thunder, and lightning. The Tribal association with the wild rice and Rice Lake cannot be measured or overemphasized, especially considering that the Mole Lake Band is situated at Rice Lake so that their members can harvest the rice. Figure 3 shows the current location of the reservation.

Boundaries: The watersheds that the reservations are part of must be recognized on a larger scale than the reservations alone because runoff from the watersheds can greatly impact the reservations.

Data Summarization: A complete analysis of the impacts to the Tribal culture is available by Cleland, Nesper, and Cleland in a report prepared by Aurora Associates, Williamston, Michigan, under contract with the Sokaogon Band of Chippewa, the Menominee Tribe of Wisconsin, and the Forest County Potawatomi, in cooperation with the GLIFWC on behalf of the Lake Superior Chippewa.

Acceptable Error Rates: Acceptable error rates have been discussed in previous PDQOs as related to modeling. Water level changes, stream discharge, seasonal sensitivities, and flood/drought intensity and duration will be examined to the extent that the needs for wild rice viability are known. Needs for viability of other biota are included in the analysis and discussed in PDQO 1(c).

1(e) Effect of Runoff Changes on Flood Frequency and Magnitude

Problem: The construction of the mine facilities will convert 550 acres of forested (main land cover), open space, and wetland areas into a mill for ore processing, a tailings-management area, a water management and treatment system, offices, maintenance shops, storage buildings, and parking (see Figures 3.1 and 3.2 in the

Simulation Plan). Surface runoff resulting from storms will be substantially higher from the constructed facilities than from the natural areas. Stormwater-management facilities will be constructed by the NMC, however, such facilities typically only mitigate increases in local flooding resulting from land-use change, whereas flooding may increase farther downstream (e.g., Dreher and others, 1991). Thus, it is necessary to evaluate the changes in downstream flooding resulting from mine construction.

Decision: Are the frequency and duration of discharges greater than <u>X</u> ft^3/s at <u>a key location along the streams substantially increased</u> for runoff after mine construction relative to the frequency resulting for runoff under natural conditions? Has the magnitude for the <u>Y</u>-year storm at <u>a key location along the streams substantially increased</u> for runoff after mine construction relative to the frequency resulting for runoff under natural conditions?

The items underlined in the above decision must be repeated as necessary to include all key locations along the streams.

Is the frequency of water levels greater than <u>X</u> ft or <u>Y</u> ft on Little Sand Lake and Rolling Stone Lake, respectively, substantially increased for runoff after mine construction relative to the frequency resulting for runoff under natural conditions?

If the answer to any of these questions is yes, then the NMC must redesign the stormwater-detention facilities such that release rates are sufficiently small to keep downstream flows and water levels within acceptable tolerances relative to flows resulting from natural conditions.

Information Needed: A long time series (20 years or more) of discharges and lake levels corresponding to hypothetical runoff from the watershed potentially affected by the mine under natural conditions are needed to establish a comparison baseline. Long time series of discharges and lake levels are needed corresponding to hypothetical runoff from the watershed under conditions of mine construction, operation, and closure. In each case, the hypothetical runoff time series is generated using identical long-term data series of meteorological conditions (precipitation, temperature, wind, radiation, etc.) collected in the vicinity of the proposed mine. The hypothetical runoff series for natural and mine conditions will then be compared as discussed in the Data Summarization section.

Boundaries: The area to which this decision will apply includes Hemlock, Swamp, and Hoffman Creeks and Little Sand and Rolling Stone Lakes (Figure 3.1 in the Simulation Plan). These water bodies were selected because they are potentially affected by changes in runoff resulting from mine construction, operation, and closure, and they all are bordered by residences or structures that could be substantially damaged by flooding. Maps of flood hazards have not been prepared for the other streams in the area because there are no residences or other structures in the vicinity of these streams, and, thus, flooding along these streams is not of vital interest at this time. Damage or change to habitat due to flooding will be considered where necessary. The time period to which this decision will apply is the period of construction, operation, and closure for the proposed Crandon Mine.

Data Summarization: The simulated long-term time series for natural and mining conditions will be summarized as frequency distributions of discharges and lake levels. The changes in exceedance frequency for specified discharges and lake levels will be determined for mining conditions compared to natural conditions. Changes in the duration of discharges and lake levels above the specified targets also will be determined for mining conditions compared to natural conditions. Finally, changes in the magnitude of discharges of specified return periods will be determined for mining conditions compared to natural conditions.

Acceptable Error Rates: Because the simulated data will be analyzed utilizing a frequency distribution, the acceptable error rate should be factored into the criteria on unacceptable increases in high discharges, lake levels, or flood magnitudes.

Selection of Resource Efficient Study Design

Achievement of PDQOs 1(b-e) require consideration of changes in frequency of discharges and (or) lake and wetland water levels resulting from mine construction, operation, and closure relative to natural conditions. Runoff from proposed mine facilities can only be assessed by simulation with a hydrology and hydraulics model with the model parameters under mining conditions adjusted as per experience with and knowledge of runoff processes on similarly altered lands. Simulated runoff for mining conditions (that is, mine construction, operation, and closure) must be compared to runoff corresponding to equivalent natural conditions. Thus, simulation of runoff from natural conditions for the same meteorological input is necessary.

The Hydrological Simulation Program Fortran (HSPF) has been successfully applied to simulate rainfall-runoff, sediment-transport, and pollutant-movement processes in watersheds for a wide variety of water-resources and environmental planning and management activities (Donigian and others, 1995). The HSPF model can be reliably calibrated and verified for natural conditions (this also will achieve PDQO 1(a)) utilizing the available hydrometeorological data as described in the “Calibration Procedures” section. Once properly calibrated for natural conditions and adjusted for mining conditions, the HSPF model can reliably simulate the long-term time series needed to achieve PDQOs 1(b-e). Therefore, runoff simulation utilizing the HSPF model was selected as the most resource efficient study design that will achieve all of the PDQOs.

II. PROJECT ORGANIZATION AND RESPONSIBILITY

This project represents a cooperative effort among the U.S. Environmental Protection Agency, Region 5 (USEPA); U.S. Geological Survey (USGS), Wisconsin and Illinois Districts; with support from Aqua Terra Consultants and the Great Lakes Indian Fish and Wildlife Commission (GLIFWC). The project officers for the Interagency Agreement (IAG) for the USEPA are Ray Marasigan and Dan Cozza, who can be reached at (312)353-1518 and (312)886-7252, respectively, at the U.S. Environmental Protection Agency, 77 West Jackson Boulevard, Chicago, Illinois 60604. Other contributors within the Agency have been from the Standards and Applied Science Branch, the Watershed and Non-Point Source Programs Branch, the Analytic Research and Technology Services Branch, and the Underground Injection Control Branch. The project officer for the IAG for the USGS is Peter Hughes at (608)821-3833 at the U.S. Geological Survey, 8505 Research Way, Middleton, Wisconsin 53562. The project contact at Aqua Terra is Tony Donigian, who can be reached at (650)962-1864 and Aqua Terra Consultants, 2685 Marine Way, Suite 1314, Mountain View, California 94043.

Others who are not part of the IAG but have graciously contributed data, field notes, planning input, (with and without USEPA funding) are John Coleman and Ann McCammon Soltis from GLIFWC, John Griffin, Robert Pillsbury, and Roman Ferdinand from the Sokaogon Chippewa Community, Mole Lake Band, Phil Seem and George Howlett of the Menominee Tribe, Joel Trick of the U.S. Fish and Wildlife Service, John Barko and Jean O'Neil from the USACE Waterways Experiment Station (WES), Don Moe from the Nicolet Minerals Company, and Steve Donohue from the NMC contractor, Foth and VanDyke.

The USEPA has the primary responsibility for model development, calibration, verification, and application to various mine construction, operation, and closure scenarios for the proposed Crandon Mine in Wisconsin. The cooperating agencies and consultants will assist the USEPA on the following tasks.

1) The USGS, Illinois District, will prepare this Quality Assurance Project Plan with advice and assistance from the USEPA.
2) The USGS, Wisconsin District, will compile the meteorological, streamflow, lake-level, and water level in wells data available for the vicinity of the proposed Crandon Mine and place these data into Watershed Data Management (WDM) files with assistance from the USGS, Illinois District.
3) The USGS, Wisconsin District, will compile the geographical data available for the vicinity of the proposed Crandon Mine into a Geographical Information System (GIS) and work with Aqua Terra on the subdivision of the watershed into drainage basins, land-use categories, and parameterization of watershed characteristics derived from the GIS data.

4) Aqua Terra will prepare a Simulation Plan and the Hydrological Simulation Program Fortran (HSPF) User-Control Input for Swamp Creek and Pickerel Creek utilizing the information provided in tasks (2) and (3) following the procedures described in the Simulation Plan, and will do some preliminary simulations for these streams.
5) Aqua Terra will give a 3-day, hands-on calibration short course for EPA personnel.
6) The USGS, Illinois District, will assist the USEPA with model calibration and verification on a hands-on basis after the short course. Aqua Terra will assist the USEPA with model calibration by phone, fax, and E-mail consultation.
7) The USGS will arrange a review of the calibrated and verified model to assure its scientific soundness.
8) All agencies and the consultants will assist the USEPA in the development of appropriate parameters and scenarios for simulation of the changes in runoff resulting from mine construction, operation, and closure conditions.
9) The USGS, Illinois District, and Aqua Terra will work with the USEPA to define appropriate sensitivity analysis methods to apply in accounting for the uncertainties in HSPF when characterizing changes in runoff resulting from mine construction, operation, and closure conditions.

Upon appropriate review and responses to that review, the USGS will confirm that the resulting models and analyses are scientifically sound and applicable. However, the decisions made with respect to the Project Data Quality Objectives on the basis of the model results are the responsibility of the USEPA.

III. QUALITY ASSURANCE OBJECTIVES FOR THE SIMULATION MODEL

A HSPF model of the rainfall-runoff process of the area potentially affected by the proposed Crandon Mine will be developed. In order to obtain reliable information to answer the questions raised in the Project Data-Quality Objectives, model parameter values must be defined for natural and mine construction, operation, and closure conditions. In this section, the statistical and graphical tools utilized to evaluate the reliability (assure the quality) of the calibration and verification of the HSPF model developed to describe the rainfall-runoff process for watersheds in the vicinity of the proposed Crandon Mine are presented. The procedures utilized to assure the quality of the simulation results for the uncalibrated, mine construction, operation, and closure conditions also are presented in this section.

<u>Acceptable Calibration and Verification</u>

HSPF calibration is performed in a stepwise manner primarily using data available at stream flow gages and matching the overall water budget, the annual water budgets, the monthly and seasonal water budgets, and finally, considering storm-runoff volumes and frequencies. In evaluating the monthly and seasonal water budgets and storm-runoff volumes, the relative proportions of high flows and low flows are considered. Several criteria must be utilized to determine if the quality of the fit between the simulated and observed runoff is acceptable. James and Burges (1982) recommend that graphical and statistical means be used to assess the quality of fit because trends and biases can be easily detected on graphs, and statistics provide an objective measure of whether one simulation is an improvement over another. A combination of graphical and statistical measures of the quality of fit will be used in this study.

For the overall and annual water budgets only the percent error will be considered. Donigian and others (1984, p. 114) state that for HSPF simulation the annual or monthly fit is very good when the error is less than 10 percent, good when the error is between 10 and 15 percent, and fair when the fit is between 15 and 25 percent. **The target for acceptable calibration and verification for this study is simulation of the overall and annual water budgets within 10 percent of the measured values.**

Plots of observed and simulated runoff will be prepared for the monthly water budget and checked for periods of consistent oversimulation or undersimulation of runoff. The quality of fit for monthly values also will be examined using three statistics: (1) the correlation coefficient between simulated and observed flows, (2) the coefficient of model-fit efficiency (Nash and Sutcliffe, 1970) between simulated and observed flows, and (3) the number of months for which the percentage error is less than a specified percentage (10 and 25 percent will be used in this study). The average relative percentage error in monthly flows over the calibration period also will be considered, but relatively small overestimates in months with very low flows may make this statistic a poor indicator of the overall quality of the fit. The correlation coefficient, C, is calculated as

$$C = \frac{\Sigma\,(Qm_i - Qm) * \Sigma(Qs_i - Qs)}{[\Sigma\,(Qm_i - Qm)^2 * \Sigma(Qs_i - Qs)^2]^{1/2}} \quad (1)$$

where Qm_i is the measured runoff volume for month i, Qs_i is the simulated runoff volume for month i, Qm is the average measured monthly runoff volume, Qs is the average simulated monthly runoff volume, and i = 1,..., N, where N is the number of months in the calibration period. The coefficient of model-fit efficiency, E, is calculated as

$$E = \frac{\Sigma(Qm_i - Qm)^2 - \Sigma(Qm_i - Qs_i)^2}{\Sigma(Qm_i - Qm)^2} \quad (2)$$

James and Burges (1982) suggest that an excellent calibration is obtained if the coefficient of model-fit efficiency exceeds 0.97, and present an example of an HSPF application where both the correlation coefficient and the coefficient of model-fit efficiency for daily flows exceeds 0.98. For the Stanford Watershed Model (a predecessor of HSPF), Crawford and Linsley (1966) reported correlation coefficients for daily flows between 0.94 and 0.98 for seven watersheds ranging in size from 18 to 1,342 mi^2 and with 4 to 8 years of data. Other researchers studying monthly flows have determined best model fits with lower correlation coefficient values. Ligon and Law (1973) applied the Stanford Watershed Model to a 561-acre experimental agricultural watershed in South Carolina and obtained a correlation coefficient and a coefficient of model-fit efficiency for monthly flows of 0.966 and 0.931, respectively, for a 60-month calibration period. Chiew and others (1991) applied HSPF to a 56.4 mi^2 agricultural watershed in west Tennessee and obtained a correlation coefficient for monthly flows of 0.8 for a 54-month calibration period. Duncker and others (1995) applied HSPF to five watersheds in Lake County, Ill., ranging in size between 6.3 and 59.9 mi^2. For a 43-month calibration period, the correlation coefficients for monthly flows ranged between 0.93 and 0.97 and the coefficient of model-fit efficiency for monthly flows ranged between 0.86 and 0.92 for best-fit calibrations, whereas for regional calibrations (in which 3 of the watersheds were calibrated jointly) and verification (on 2 watersheds) the correlation coefficient ranged between 0.93 and 0.95 and the coefficient of model-fit efficiency ranged between 0.86 and 0.91. Donigian (Aqua Terra Consultants, written communication, 1997) indicated that in areas where snowmelt is a major factor and meteorological data are sparse, it may be difficult to obtain the high correlation coefficients and coefficients of efficiency reported in the previously listed studies. **The targets for acceptable calibration and verification of monthly flows are a correlation coefficient greater than 0.85 and the coefficient of model-fit efficiency greater than 0.8.**

The daily flows will be checked graphically by comparing the observed and simulated runoff-duration curves and time series. General agreement between the observed and simulated runoff-duration curves indicate adequate simulation over the range of the simulated flow conditions. Substantial or consistent departures between the observed and simulated runoff-duration curves indicate inadequate calibration. Three statistics are utilized in the expert system for calibration of HSPF, HSPEXP (Lumb and others, 1994), to numerically evaluate the high-flow/low-flow distribution indicated in a flow-duration curve. These statistics and the HSPEXP default criteria are given in the following.

1) The error in the mean low-flow-recession rates based on the computed ratios of daily mean flow today divided by the daily mean flow yesterday for each day for the highest 30 percent (or other user-selected value) of the ratios less than 1 (i.e. during flow

recession). The default allowable difference in the mean low-flow-recession rate is ≤ 0.02.
2) The error in the mean of the lowest 50 percent of the daily mean flows. The default allowable error is ≤ 10 percent.
3) The error in the mean of the highest 10 percent of the daily mean flows. The default allowable error is ≤ 15 percent.

The target criteria for acceptable calibration and verification for the high-flow/low-flow distribution in the simulated runoff relative to measured runoff are a mean low-flow-recession rate difference ≤ 0.02, an error in the mean of the lowest 50 percent of the daily mean flows ≤ 10 percent, and an error in the mean of the highest 10 percent of the flows ≤ 15 percent.

The quality of fit for the larger storms will be measured graphically by the agreement between the simulated and observed partial-duration series of runoff volumes. The annual probability of exceedance of each storm will be determined according to Langbein (1949). Also, the following criteria are utilized in the HSPEXP (Lumb and others, 1994) for storm volumes: (1) the error in total flow volumes for the sum of up to 36 selected storms must be less than 20 percent, and (2) the error in total flow volumes for the sum of selected summer storms must be less than 50 percent. Runoff volumes are used in this study because changes in lake water levels are dependent on accurate simulation of runoff volumes. **The criteria for acceptable calibration and verification for storm-runoff simulation are (1) the error in total flow volumes for the sum of up to 36 selected storms must be less than 20 percent, and (2) the error in total flow volumes for the sum of selected summer storms must be less than 50 percent.**

Accurate simulation of lake and wetland levels is a vital component of evaluating the effects of the proposed Crandon Mine on surface-water resources in the vicinity of the mine. Therefore, calibration also will consider accurate simulation of available monthly lake-level and water level in wells data in the Swamp Creek watershed. Verification will be done by spatial transposition of the calibrated model as well as temporal transposition of the calibrated model. Verification through spatial transposition involves application of the runoff relations calibrated for the Swamp Creek watershed to the Pickerel Creek watershed and utilizing lake-level and water-level in wells data in the Pickerel Creek watershed to evaluate the reliability of the calibrated HSPF model. Verification through temporal transposition involves application of the runoff relations calibrated for a given time period to a second independent time period and utilizing discharge, lake-level, and water level in wells data to evaluate the reliability of the calibrated HSPF model.

The accuracy of the calibration and verification for monthly lake-level and water level in wells data will be evaluated using the correlation coefficient and coefficient of model-fit efficiency previously described. Maximum and average errors in water levels also will be considered relative to the range of water-level fluctuations for a given lake or wetland. **The targets for acceptable calibration and verification of monthly water levels are a correlation coefficient greater than 0.85 and the coefficient of model-fit efficiency greater than 0.8.** However, it may be necessary to adjust these targets during calibration and verification because (1) the lake and wetland level data available for calibration and verification are limited temporally, (2) the available data on elevations and lake/wetland characterization (e.g., bathymetry and stage-discharge relations) are less reliable than other data utilized in model development, and (3) less experience is available with the wetland water level simulation in HSPF12 than for other aspects of HSPF.

<u>Characterization of Post-Construction Conditions</u>

Characterization of runoff processes during mine construction, mine operation, and mine closure is more complicated than characterization of natural conditions because mine conditions cannot be evaluated by calibration due to a lack of data. Simulation of the hydrologic effects of mine operation must consider the following issues.

1) For all land-use/land-cover types in the vicinity of the mine, the lowering of the water table resulting from mine pumping must be accounted for by adjusting the direct simulation of the water table in the unsaturated zone simulation in HSPF12.
2) HSPF parameter values must be defined for new land-use/land-cover types: mine-affected area and tailings-management area.

The mine-affected area will be a combination of impervious surface and compacted open space, whereas the tailings management area is an unique land use/land cover. A literature search will be done to determine the changes in runoff resulting from mine areas of the type proposed. These documented changes in runoff will be used as guidelines for altering HSPF parameter values to reflect the effects of changes in land use in the mine-affected areas. Ranges of parameter values will be established and sensitivity-analysis methods will be applied to determine the expected value of and ranges for runoff, lake levels, and water levels in wells for the watersheds affected by mine operations. The expected values and ranges will be used to determine which conditions result in substantial changes in runoff and water levels relative to baseline (current, natural) conditions.

IV. CALIBRATION PROCEDURES

The water budget for a watershed is simulated in HSPF on a continuous basis by subdividing the watershed into areas of specified land use/land cover (soil type is an important factor if substantial variations in the hydrologic properties of soils are present within the watershed) and summing the runoff from each of these areas. The locations of the land use/land cover types within the watershed do not substantially affect the water budget. If streamgage data are available at the outlet of a watershed, model parameter values can be determined by calibration and tested in verification wherein hydrologically defined differences between runoff processes on different land-use/land-cover types are maintained in the calibration process (for example, forest areas should have higher evapotranspiration and interception than grassland areas). In this project, verification also will be done by spatial transposition of the model calibrated for runoff estimation on the Swamp Creek watershed (as described in the following paragraphs) to runoff estimation on the Pickerel Creek watershed. Thus, the lake-level and water level in wells data available in the Pickerel Creek watershed will be used to evaluate the reliability of the calibrated HSPF model.

For the area of the proposed Crandon Mine, model-parameter values reflecting the current, natural conditions (land-use/land-cover types, see Figure 3.2 in the Simulation Plan) can be determined by calibration and verification utilizing runoff data at the Swamp Creek above Rice Lake and Swamp Creek below Rice Lake at Mole Lake, Wisconsin, stream gages assuming adequate daily and hourly rainfall data and other meteorological data can be obtained. Flow from much of the area potentially affected by the proposed mine and representative of the remaining affected area in the Pickerel Creek watershed is measured at the Swamp Creek above Rice Lake streamgage. The data from the gage below Rice Lake will be used to ensure flows and water levels in Rice Lake are correctly represented in the model.

Runoff from a 46.3 mi^2 portion of the Swamp Creek watershed including a part of the proposed mine site was measured at the gage above Rice Lake from August 1977 to September 1983 and from October 1984 to December 1986. Runoff from a 56.7 mi^2 portion of the Swamp Creek watershed was measured at the gage below Rice Lake from August 1977 to September 1979 and from April 1982 to June 1985. Streamflow was estimated for each gage site for the periods when the gage was not operational utilizing the data at the other gage. Thus, runoff data are available for a period of 9 years and 3 months at these gages. Locations of climatological and streamflow stations near the proposed Crandon Mine are shown in Figure 1.1 in the Simulation Plan.

The 9-year period of streamflow data will be subdivided into a 5-year calibration period and a 4-year verification period. The calibration period exceeds the length of record (3-5 years) recommended as the minimum for adequate model calibration (Donigian and others, 1984; Linsley and others, 1982, p. 347). Because water levels in lakes and wetlands are important decision parameters and water levels in selected wetlands will be explicitly simulated in HSPF12 (see the “Analytical Procedure to Evaluate Changes in Runoff” section), the availability of data on lake and wetland water levels in wells are important to selecting the calibration and verification periods. Water-level data are

available on a monthly basis sporadically from 1977 to 1995 for 314 observation wells in the vicinity of the proposed Crandon Mine (Figure 7). Lake-level data are available on a monthly basis sporadically from 1977 to 1995 for Deep Hole Lake, Duck Lake, Little Sand Lake, Oak Lake, Rolling Stone Lake, Rice Lake, Skunk Lake, Ground Hemlock Lake, Hoffman Spring, St. John's Lake, and Walsh Lake. To obtain the most reliable calibration possible, the calibration period will be selected to include as much lake level and water level in wetlands data as possible.

Verification also will be evaluated by applying the HSPF model with parameters determined for the Swamp Creek Basin to the Pickerel Creek Basin, simulating monthly lake and wetland water levels, and comparing the simulated values to the measured values.

Initial values for model parameters will be selected from the results of previous studies on similar watersheds (for example, Donigian and Davis, 1978, and recent experience in the Minnesota River Basin), watershed characteristics, and preliminary model simulations. Relatively little experience is available with the wetland hydrology algorithms, but recent applications in Florida will be used to guide selection of the initial parameter values for this study. In the preliminary simulations, initial values for storage parameters are selected by setting the values to nominal storage values and simulating several years of streamflow. Storage values are equilibrated in model simulation over time. Values for the storage parameters for the initial month of model simulation are then determined from the storage parameter values for the same month in subsequent years. Figure 5 shows a schematic diagram of the HSPF model.

The calibration process will then be facilitated by the use of the HSPEXP (Lumb and others, 1994). The basis of the HSPEXP is that "in more than two decades of experience with HSPF and similar models over a wide range of climates and topographies, experienced modelers have learned which parameters can be meaningfully adjusted to reduce the error of estimate" (Lumb and others, 1994). The HSPEXP evaluates the 7 error criteria discussed in the "Quality Assurance Objectives for the Simulation Model" section and provides calibration advice on which parameters to change on the basis of the computed error criteria and target acceptance levels. The HSPEXP includes 79 rules that result in calibration advice that applies to the 12 major, process-related parameters in HSPF. The calibration advice has three aspects: (1) the conditions that cause the advice to be given, (2) the advice that suggests an increase or decrease in a parameter value, and (3) why the advice is given for the stated conditions. An example of this advice is given in the following:

Problem: The simulated total runoff (_) is greater than the
observed (_), and LZSN times 1.5 is below the available
water capacity of the soil for the estimated rooting depth

To correct this problem: increase LZSN

Explanation: If potential evapotranspiration and the transpiration factor for vegetal cover (LZETP) are sufficiently high and the subsurface losses are appropriate, then the only way to decrease flow is to increase the storage capacity (LZSN) to provide greater opportunity for evapotranspiration.

From this rule the physical relation between LZSN and the available water capacity of the soil is indicated.

The amount to change a parameter is not indicated in the advice given by the HSPEXP. The user must select the appropriate change. Eleven different plots can be generated utilizing the HSPEXP to visually assess calibration quality and assist the user in selecting an appropriate change. These plots are:

1) Measured and simulated daily flow
2) Measured and simulated monthly flow
3) Daily upper-zone storage and error between simulated and measured daily flows
4) Daily lower-zone storage and error between simulated and measured daily flows
5) Error between simulated and measured daily flows
6) Measured daily flow and error between simulated and measured daily flows
7) Weekly evapotranspiration
8) Flow-duration curve
9) Hydrographs for user-selected storms
10) Base-flow recession
11) Cumulative error between measured and simulated daily flows

If the change in a parameter value is too small, the same advice will result in the next run of HSPEXP. Whereas if the change in a parameter value is too large, the opposite advice will result in the next run of HSPEXP. The acceptance criteria discussed in the "Quality Assurance Objectives for the Simulation Model" section may be tightened as calibration proceeds. A point will be reached in the process of tightening the acceptance criteria where no parameter sets can meet all criteria resulting in an infinite loop adjusting and readjusting with no real improvement in calibration. At this point, calibration should end (Lumb and others, 1994).

Each of the calibration rules relates the adjustment of a parameter to a runoff feature of the simulated continuous hydrograph. The relative importance of the various parameters to accurate calibration of HSPF to the measured runoff can be assessed by the number of calibration rules related to the various parameters. The runoff features affected and the number of calibration rules for each of the model parameters is listed in Table 1. From Table 1 it is clear that approximately 5 parameters are the most important in calibration of HSPF, but depending on site-specific conditions other parameters may be important. Experience in Lake (Duncker and others, 1995) and Du Page (Duncker and Melching, 1998) Counties in Illinois also indicates that approximately 5 or 6 parameters are most important in calibration of HSPF (although not exactly the same list of important HSPF parameters as indicated in HSPEXP).

The results obtained from HSPEXP will not be the sole basis of the calibration of HSPF. Lumb and others (1994, p. 2) state that in part the HSPEXP was developed so that "less-experienced modelers can manually calibrate the model and improve their understanding of the link between the simulated processes and the actual processes." Further, the HSPEXP was developed for use with HSPF11 and earlier versions. The statistics computed and the plots generated with the HSPEXP are valuable for assessment of the results from HSPF12, but the calibration advice may not be sufficient for calibration of HSPF12 for this project. Specifically, the HSPEXP does not provide guidance for calibration of snow accumulation and melt nor for the wetlands/water table capabilities of HSPF12. The HSPEXP will be utilized to compute statistics, generate plots, and provide overall calibration advice. However, the final fine tuning of the model and the primary calibration advice for HSPF12 will be derived from the experience of Aqua Terra Consultants and the USGS. This combination of calibration advice derived from the experts assisting with the modeling and the HSPEXP should result in a physically defensible calibration and verification of HSPF for the vicinity of the proposed Crandon Mine.

V. ANALYTICAL PROCEDURE TO EVALUATE CHANGES IN RUNOFF

Estimates of the changes in runoff resulting from the construction, operation, and closure of the proposed Crandon Mine are needed to answer the questions raised in the Project Data Quality Objectives. Because the mine is proposed and not yet constructed, a procedure must be developed to estimate changes in runoff relative to natural conditions resulting from mine construction, operation, and closure. Runoff from natural conditions can be assessed on the basis of available data for the watersheds near the proposed mine. However, runoff from the modified conditions of mine construction, operation, and closure cannot be assessed on the basis of available data for watersheds near the proposed mine. Therefore, a computer model that is capable of simulating runoff resulting from natural and mine conditions through physically defensible selection of model-parameter values must be used to evaluate changes in runoff. The model-parameter values corresponding to natural conditions can be determined by calibration and verification utilizing available data. The model-parameter values corresponding to mine conditions may be estimated from published runoff information for similar mines and experience with the selected computer model. The calibration procedure is described in detail in the "Calibration Procedures" section and the acceptable accuracy of calibration and the quality assurance of the uncalibrated model parameters are described in detail in the “Quality Assurance Objectives for the Simulation Model” section.

The model selected to simulate the rainfall-runoff process in the watersheds potentially affected by the proposed Crandon Mine is the Hydrological Simulation Program Fortran (HSPF) (Bicknell and others, 1997). HSPF has been successfully applied to simulate rainfall-runoff, sediment-transport, and pollutant-movement processes in watersheds for a wide variety of water-resources and environmental planning and management activities (Donigian and others, 1995). For these planning and management activities, HSPF is utilized to simulate 20- to 40-year time series of runoff (depending on the length of record for reliable meteorological data). Key runoff statistics computed for the simulated runoff are computed and compared for baseline (current) and altered conditions. Because continuous runoff and transport processes are simulated, considerable flexibility is available in HSPF to describe changing watershed conditions, and a multi-year range of changes in runoff may be obtained. HSPF simulation is particularly useful in assessing changes in runoff and pollutant loads resulting from land-use and management-practice changes in a watershed. Therefore, HSPF is well suited for estimating changes in timing and magnitude of streamflow and lake and wetland water levels resulting from mine construction, operation, and closure.

HSPF is a conceptual model that approximates the land-surface portion of the hydrologic cycle by a series of interconnected water storages: an upper zone (UZS), a lower zone (LZS), and a ground-water zone (GWS). The amounts of water in these storages and the flux of water between the storages and to the stream or atmosphere are simulated on a continuous basis for a subarea of a given land cover and precipitation input. The fluxes of water between storages and to the stream or atmosphere are controlled by model parameters. The model parameters have physical meaning conceptually; some are physically measurable but most must be determined by calibration. The model parameters include partition coefficients and linear reservoir-release coefficients. Model parameters and their function are listed in Figure 5.

The flow paths through the upper, lower, and ground-water zones and the relations between the storage in the zones and streamflow and evapotranspiration are shown in Figure 5. The upper zone usually consists of surface vegetation, ground litter, and the upper several inches of soil. Surface runoff and prompt subsurface flow (interflow) are affected by storage in the upper zone. The lower zone is the zone from which deeply rooted vegetation draws water. This water is then lost to the atmosphere through evapotranspiration. The lower zone contains water stored in the soil that does not discharge to the stream. The ground-water zone stores the water that produces base flow in the stream during and between storms. Water also can be lost to deep ground water that does not flow to the stream from the ground-water zone.

The previous description of HSPF refers primarily to Release 11 (HSPF11) and earlier versions. A modification has recently (1996) been made to HSPF (HSPF12) that attempts to improve simulation of the rainfall-runoff process in areas with high water tables and (or) wetlands (Hydrocomp, Inc. and Aqua Terra Consultants, 1996). In HSPF12, the lower-zone and upper-zone storages are tied explicitly to the fillable porosity of the soil in the unsaturated and near-surface-storage zones so that the elevation of the water table and interactions between the saturated (ground water) and unsaturated zones may be simulated. The redefined lower and upper zones are illustrated in Figure 6. Thus, the effects of a high water table on surface runoff, interflow, and ground-water discharge can be more reliably simulated. In HSPF12, ground water discharges to the stream whenever the water table is above a user-defined base elevation (BELV in Figure 6) that generally represents the bottom of a nearby stream channel. Also in HSPF12, when the water table reaches the ground surface, the water goes into surface storage from which water directly evaporates and runs off as a function of storage instead of slope. These modifications improve the physical basis of HSPF as measurable parameters, such as fillable porosity, are added to the model.

Calibration and verification of the fluctuating water table require detailed water-table and stream-bed elevation data for the areas with high water tables and (or) wetlands. Water-level data are available on a monthly basis sporadically from 1977 to 1995 for 314 observation wells in the vicinity of the proposed Crandon Mine (Figure 7). The locations of these wells will be compared to wetland locations and those wetlands for which water-level data from wells are available will be explicitly modeled as wetlands with a fluctuating water table in HSPF12. Other wetlands for which water-level data from wells are not available will be modeled as pervious land segments as in HSPF11. Nearly all the observation wells are located in the southern portion of the Swamp Creek watershed and the northern portion of the Pickerel Creek watershed, as shown in Figure 7. Thus, the wetlands closest to and most affected by the proposed mine could be simulated explicitly with HSPF12 (depending on well locations). Because of the substantial topographic variation in the Swamp Creek and Pickerel Creek watersheds and the location of wetlands primarily along the streams and lakes, the water budget in the other wetlands may be reliably simulated with HSPF11. The simulation of the various wetlands with HSPF11 or HSPF12 methods (both may be included in HSPF12) will not substantially alter the quality-assurance objectives for the calibrated and verified models or the procedures utilized to evaluate the changes in runoff resulting from the proposed mine.

In application of HSPF, each watershed studied is subdivided on the basis of rain-gage locations and land-cover categories. Rainfall data from the rain-gage network are typically distributed by application of the Theissen polygon method. A watershed is divided into several polygons that represent the portion of the watershed nearest to a given rain gage. Each of the polygons is assigned an amount of rainfall from the nearest rain gage. Land-cover data are aggregated into pervious (PERLND) and impervious (IMPLND) categories for each of the Theissen polygons. The pervious (PERLND) category is further subdivided into grass (open space), wetland, forest, and other land-cover categories. A wide range of physical attributes can be assigned to a PERLND or IMPLND to represent various land-cover conditions through the selection of model parameters.

The primary purpose of segmenting the watershed is to divide the study area into land segments that are assumed to produce a homogeneous hydrologic and water-quality response. The segmentation allows the user to assign identical model parameter values to all parts of the watershed that produce the same unit response of runoff for a uniform set of meteorologic conditions. Where meteorological conditions vary substantially across a watershed, the land segments also are divided to accurately represent the meteorological variations and their effects on the runoff quantity and quality from the watershed. Segmentation is also used to obtain output at points of interest in the watershed for decision making. Full details on the segmentation of Swamp and Pickerel Creeks for this project are described in the Simulation Plan developed by Aqua Terra Consultants.

VI. INTERNAL QUALITY-CONTROL CHECKS

Quality-control checks are required for two aspects of the HSPF modeling effort: (1) the meteorological, streamflow, lake-level, and water level in wells data utilized to calibrate and verify the model, and (2) the assumptions and procedures utilized to calibrate and verify the model to the available data and to parameterize the model for mine construction, operation, and closure conditions.

The streamflow data for Swamp Creek above Rice Lake were rated by the USGS as "fair" from August 1977 through September 1978 because the gage was in backwater from Rice Lake and bridge construction. These data were then rated as "good" except for ice periods which were rated "fair" from October 1978 through December 1986 due to the construction of a concrete control at the bridge on State Highway 55. The streamflow data for Swamp Creek below Rice Lake were rated "good" except for winter periods and a period of backwater from beaver activity which were rated "fair" between August 1977 and September 1978 and were rated "fair" between April 1982 and June 1985 again because of backwater from beaver activity. Ratings of "good" and "fair" mean that about 95 percent of the daily discharges are within 10 percent and 15 percent of the true value, respectively.

The meteorological data will be retrieved from the National Weather Service (NWS). Standard NWS techniques will be applied to fill in missing rainfall record and doublemass curves will be utilized to examine the consistency of the data collected at the rain gages.

The lake-level and water level in wells data will be checked in detail by Aqua Terra, USGS, and USEPA personnel to detect data transcription errors. These data also will be plotted and values that appear to be outliers will be compared to rainfall and evaporation data to determine if the values are reasonable. Table 1 shows the data files, sources of data, disaggregation of data, and reviewers.

The calibration process also will provide data-quality checks. For example, convective storms may have a small enough areal extent that they may pass over Swamp Creek, but not any of the rain gages; or over one of the rain gages and not Swamp Creek. Inability to accurately simulate these periods will help identify problems with data representativeness.

In summary, the streamflow data on Swamp Creek above Rice Lake already have been evaluated as “fair to good” by the USGS. The rating “good” is the highest rating the USGS will assign to data collected at any streamgage. A rating of “excellent” is discussed in USGS Annual Water-Resources Data reports wherein about 95 percent of the daily discharges are within 5 percent of the true value. However, this rating is almost never used even for gages where highly accurate acoustic velocity meters are utilized to continuously measure velocity with an accuracy of 1 to 2 percent. Therefore, ratings of “good” for a standard gage and “fair” for a gage affected by ice or beaver dams are as accurate as possible for any streamgage. The rainfall, lake-level, and water level in wells data will be analyzed for quality utilizing standard methods. Finally, the calibration process will provide a final quality check of the data.

The quality-control check for the assumptions and procedures utilized to calibrate and verify the model to the available data and to parameterize the model for mine construction, operation, and closure conditions will be provided through review of modeling documentation by HSPF experts in the USGS outside of the Illinois District. The comments from the USGS review will be used to improve the physical basis of the model as applied to decision making for the PDQO’s. All comments from the USGS will be completely addressed in a professional, scientific manner.

Table 1.

Data for Model WDM file					
File name	Description	Source	Format	Reviewer	Reviewer
101	Swamp Creek below Rice Lake, 1977-79, 82-85	USGS ADAPS Database	Digital Flat File		

Data for Model WDM file					
102	SC above RL 1977-87 (83-85 est.)	USGS ADAPS Database	Digital Flat File		
103	Wolf River at Langlade 1966-79, 80-96	USGS ADAPS Database	Digital Flat File		
200	Summit Lake PRCP 1948-95	MICIS Database	Digital Flat File		
201	Crandon Ranger Station PRCP 1948-97	MICIS Database	Digital Flat File		
202	Laona 6 SW PRCP 1948-97	MICIS Database	Digital Flat File		
203	Laona Daily Temp 1948-97	MICIS Database	Digital Flat File		
204	Laona daily max temp 1948-97	MICIS Database	Digital Flat File		
205	Laona daily min temp 1948-97	MICIS Database	Digital Flat File		
206	Laona daily snowfall 1948-97	MICIS Database	Digital Flat File		
207	Minocqua Dam daily temp 1905-97	Robertson USGS	Digital Flat File		
208	Minocqua Dam daily PRCP 1905-97	Robertson USGS	Digital Flat File		
209	Rainbow Reservoir daily PRCP 1948-96	MICIS Database	Digital Flat File		
210	Rainbow Reservoir daily temp 1948-96	MICIS Database	Digital Flat File		
211	North Pelican Daily Temp. 1950-97	MICIS Database	Digital Flat File		
212	North Pelican Daily PRCP 1948-97	MICIS Database	Digital Flat File		
213	vacant	MICIS Database	Digital Flat File		
214	South Pelican Daily PRCP 1948-96	MICIS Database	Digital Flat File		
215	Antigo Daily Temp. 1948-97	MICIS Database	Digital Flat File		
216	Antigo Daily PRCP 1948-97	MICIS Database	Digital Flat File		
217	Rhinelander PRCP 1948-97	MICIS Database	Digital Flat File		

Data for Model WDM file					
218	Rhinelander Temp. 1948-97	MICIS Database	Digital Flat File		
219	Three Lakes Daily PRCP 1948-96 (80% missing)	MICIS Database	Digital Flat File		
220	Green Bay Airport Hourly PRCP 1948-97				
221	Three Lakes Hourly PRCP 1948-96				
222	White Lakes Hourly PRCP 1958-96				
301	Laona surface water elev.	CMC EIR			
302	Crandon well BE-211-01 water level	CMC EIR			
303	South Pelican surface water data	CMC EIR			
505	Green Bay Airport (GBA) daily temp 1949-97				
506	GBA wind direction 1949-97				
507	GBA dewpoint 1949-97				
508	GBA relative humidity 1949-97				
509	GBA wind speed 1949-97				
600	Minocqua Dam sky cover 12/14/78-12/31/95 composite Minocqua, Rainbow, model	USGS/ Robertson	Digital flat file		
601	Minocqua Dam solar radiation 12/14/78-12/31/95	USGS/ Robertson	Digital flat file		
602	Minocqua Dam evaporation 1/1/80-12/31/95	USGS/ Robertson	Digital flat file		
603	Minocqua Dam wind direction 1/1/80-12/31/95	USGS/ Robertson	Digital flat file		
900	Deep Hole Lake SW elevation	CMC EIR	Paper/elec-tronic	USEPA/ JBC	GLIFWC
901	Duck Lake SW	CMC EIR	Paper/elec-tronic	USEPA/ JBC	GLIFWC
902	Little Sand Lake SW	CMC EIR	Paper/elec-tronic	USEPA/ JBC	GLIFWC
903	Oak Lake SW	CMC EIR	Paper/elec-tronic	USEPA/ JBC	GLIFWC

Data for Model WDM file					
904	Rice Lake SW	CMC EIR	Paper/elec-tronic	USEPA/ JBC	GLIFWC
905	Rolling Stone Lake SW	CMC EIR	Paper/elec-tronic	USEPA/ JBC	GLIFWC
906	Hoffman Spring SW	CMC EIR	Paper/elec-tronic	USEPA/ JBC	GLIFWC
907	St John's Lake SW	CMC EIR	Paper/elec-tronic	USEPA/ JBC	GLIFWC
908	Skunk Lake SW	CMC EIR	Paper/elec-tronic	USEPA/ JBC	GLIFWC
909	Walsh Lake SW	CMC EIR	Paper/elec-tronic	USEPA/ JBC	GLIFWC
910	Ground Hemlock	CMC EIR	Paper/elec-tronic	USEPA/ JBC	GLIFWC
3003	Three Lakes Hourly PRCP disaggreg, fill GBA /White Lk.				
3004	Summit Lake Hourly PRCP disaggreg, fill Laona & 3003				
3006	Laona daily hourly PRCP disaggreg, fill 3003 & Summit				
3008	North Pelican hourly PRCP disaggreg, fill 3003, Sum&Lao				
3010	South Pelican hourly PRCP disaggreg, fill 3003, Sum&Lao				
3012	Crandon Hourly PRCP disaggreg, fill 3003, Sum&Lao				
3013	Swamp Creek below Rice Lake discharge-fill w/above RL				
3014	Swamp Creek above Rice Lake discharge-fill w/below RL				
3015	Laona Hourly Temperature metcmp software, Lao&GB				

VII. MODEL-OUTPUT REDUCTION AND REPORTING

In the application of HSPF to water-resources management, typically, a long (20 years or more) continuous series of runoff is computed on the basis of available meteorological data, and changes in the magnitude and timing of runoff resulting from a change in the watershed are considered statistically. For example, after a watershed is changed from farmland to urban land, the number of floods with peak discharges greater than X during a period of 40 years doubled and the number of periods with zero flow increased from 1 to 5 in 40 years. For the watersheds potentially affected by the proposed Crandon Mine, hourly discharge and lake-level and wetland-level data can be generated for selected points in the watersheds for the 18-year period (1978-95) for which meteorological data are available. This period may be expanded if long-term meteorological data from more remote locations, such as Minneapolis, Minnesota, are applied to periods prior to 1978. As discussed in the "Data Summarization" subheadings in the descriptions of the PDQOs, the simulation results are reduced to frequency distributions of discharges and lake levels to answer the questions in PDQOs 1(b-e). For PDQO 1(a), the simulation results are reduced to a series of monthly lake levels that will be compared with the measured series of monthly lake levels.

VIII. PERFORMANCE AND SYSTEM AUDITS

A manual procedure is used in HSPF model calibration even when the HSPEXP is applied. In this procedure, the model user decides which parameter values are changed and by how much for each calibration simulation. Thus, it is essential to keep an iteration log during the manual calibration process. The composition of this log and the manual calibration procedure follow the steps listed below.

1) The log starts with a list of the initial values of all key parameters (see "Calibration Procedures" section) and the values of the statistical acceptance criteria (see "Quality Assurance Objectives for the Simulation Model" section) corresponding to a simulation applying these parameter values.
2) Each subsequent iteration is numbered and dated, and the changes in the parameter values and the corresponding values of the statistical acceptance criteria are recorded.
3) When approximate convergence is achieved for a key parameter value or some other key combination of parameter values is attained, an intermediate calibration point is reached. For this point, the iteration is numbered and dated and a complete list of the values of all key parameters is recorded along with the corresponding values of the statistical acceptance criteria.
4) A new calibration direction (for example, a different key parameter is varied) is then started, each iteration along this direction is numbered and dated, and the changes in the parameter values and the corresponding values of the statistical acceptance criteria are recorded. The intermediate calibration points recorded in detail in step (3) allow the user to return to a "good" point in the calibration if the new direction does not result in an improved calibration.

5) If a new intermediate calibration point is reached, the calibration process and log records return to step (3). If the new calibration direction does not result in an improved calibration, another new calibration direction is selected and the change in calibration direction is recorded in the log, parameter values return to the previous intermediate calibration point, and the subsequent log entries proceed as in step (4). If no new calibration direction is available, the calibration procedure is completed and the previous intermediate calibration point becomes the calibrated model and this result is recorded.

The iteration log provides a detailed record of all calibration iteration results and assumptions. Further, the results of the model verification and scenario simulations will be included in the project summary report. Therefore, the iteration log and project summary report provide a detailed record of the project suitable for Performance and System Audits.

IX. QUALITY-ASSURANCE REPORTS TO MANAGEMENT

As described in the “Project Organization and Responsibility” section, this project is a cooperative effort among three agencies: the USEPA, USGS, Illinois and Wisconsin Districts, and Aqua Terra Consultants. GLIFWC, FWS, WES, the Mole Lake Band and the Menominee have made a significant contribution to this project. Therefore, communication among these agencies is imperative for successful completion of the project. Throughout the initial months of the project, monthly conference calls were held to coordinate activities among the agencies. From April 28 to May 1, 1997, all involved governmental parties met near the proposed mine site and developed a preliminary timetable for the project as follows. As of this writing, the goals of the schedule are on target but the timing is now behind by approximately three months,
and the new schedule approximation follows in parentheses.

1) Develop simulation plan including preliminary watershed segmentation, listing of data to be utilized, and Quality Assurance Project Plan (QAPP).
2) Submit draft plan for review by June 1, 1997. (August, 1997)
3) Revise simulation plan and QAPP.
4) Develop WDM files of meteorological and streamflow data by August 1, 1997. (April, 1998)
5) Develop HSPF input (UCI file) for Swamp Creek and complete preliminary runs by September 15, 1998. (February, 1998)
6) Conduct workshop on model calibration in early to mid October, 1997. (Same)
7) Complete calibration and verification for Swamp Creek by early December 1997. (April, 1998)
8) Develop UCI file for Pickerel Creek and gross-scale model for the Wolf River and make preliminary runs for Pickerel Creek by early December 1997. (May, 1998)

9) Review of final calibration and verification results obtained by the USEPA by the USGS, Illinois District, and Aqua Terra by January 1998. (May, 1998)

10) Evaluation of scenarios describing mining conditions beginning in January 1998. (June, 1998)

For the timetable listed above, it is clear that the project includes completion of project steps on a nearly monthly basis. The reports resulting from the completion of these steps will constitute a fairly regular set of progress reports to management. Thus, a formal monthly progress report is not necessary for this project. Further, regularly scheduled (approximately monthly) conference calls will continue throughout the duration of the project.

Table 2--Runoff features affected by the model parameters in the Hydrological Simulation Program Fortran (HSPF) and the number of calibration rules in the expert system for calibration of HSPF related to each parameter and runoff feature.

Parameter	Runoff Features Affected	Number of Rules
LZETP	Overall water balance Seasonal runoff distribution	12 2
INFILT	Overall water balance High flow-low flow distribution Stormflow	6 6 2
LZSN	Overall water balance High flow-low flow distribution	4 6
INTFW	Stormflow	10
IRC	Stormflow	8
DEEPFR	Overall water balance High flow-low flow distribution	3 1
AGWRC	High flow-low flow distribution	4
UZSN	Seasonal runoff distribution	4
PRIMP*	Seasonal runoff distribution	4
BASETP	High flow-low flow distribution Seasonal runoff distribution	1 2
KVARY	Seasonal runoff distribution	3
CEPSC	Seasonal runoff distribution	2

*PRIMP is not a defined model parameter, it is the percent impervious for the entire watershed.

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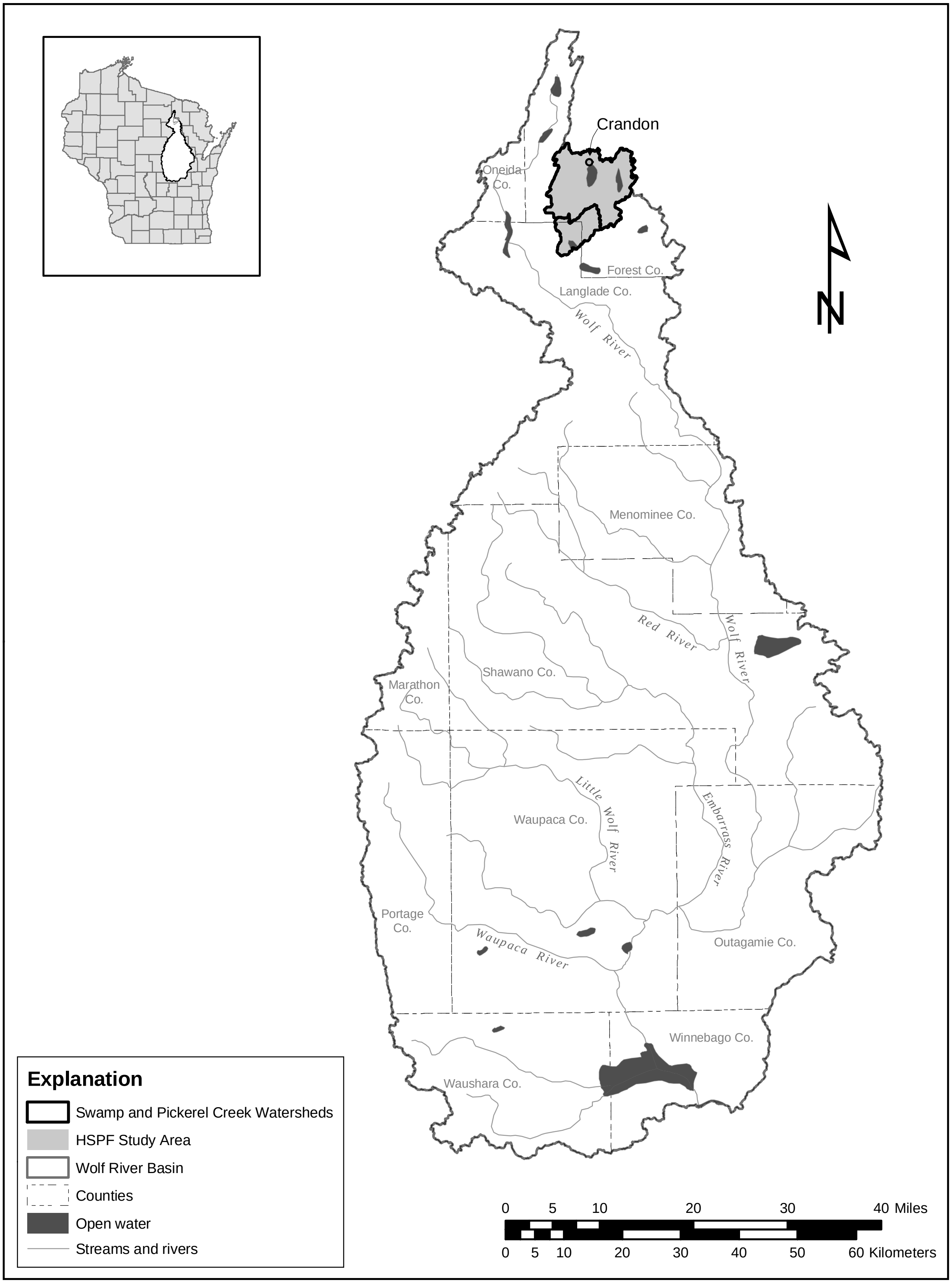


Figure 1. Location of the study area within Wolf River Basin in Forest and Langlade Counties, Wisconsin.

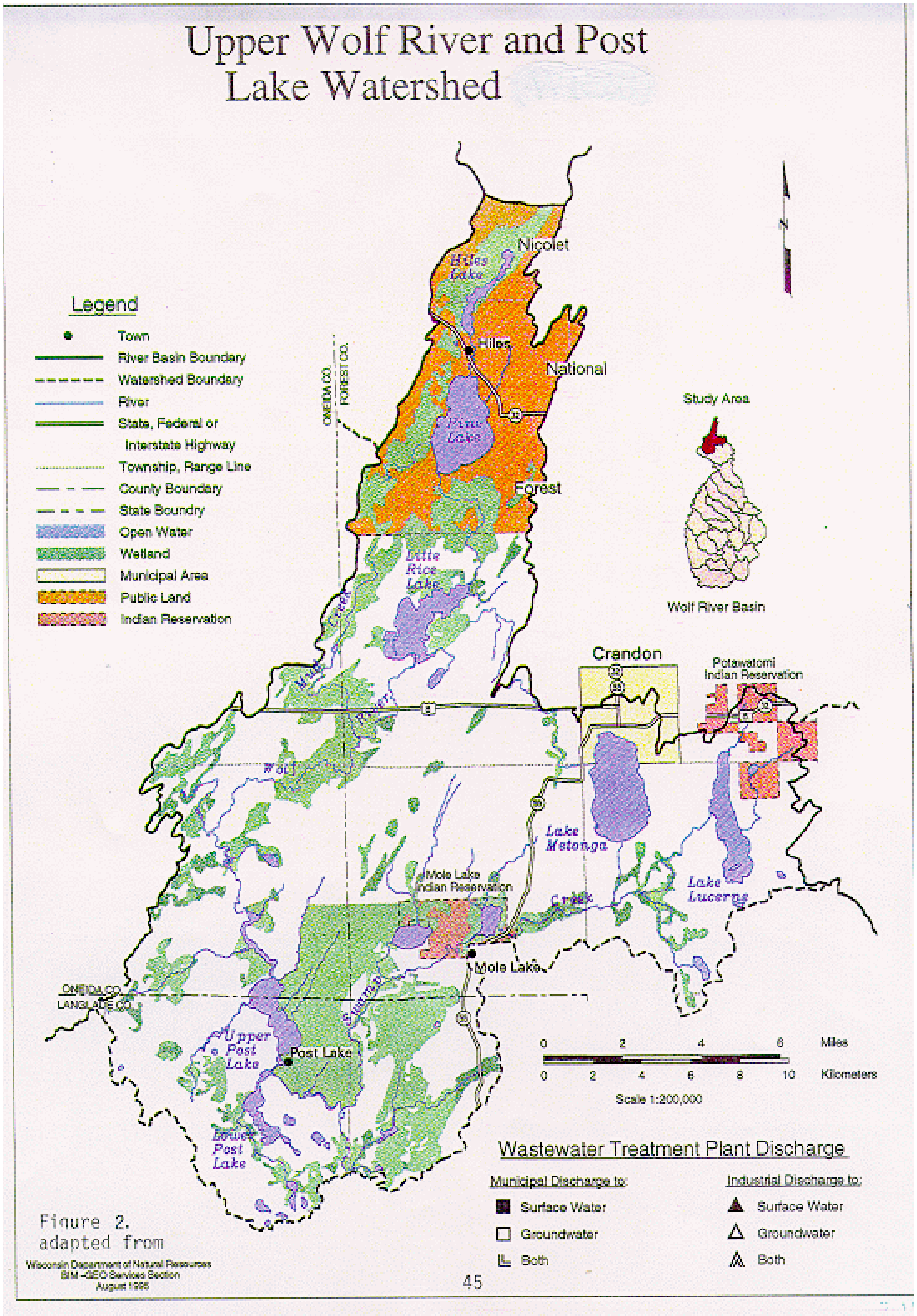


Figure 2. adapted from

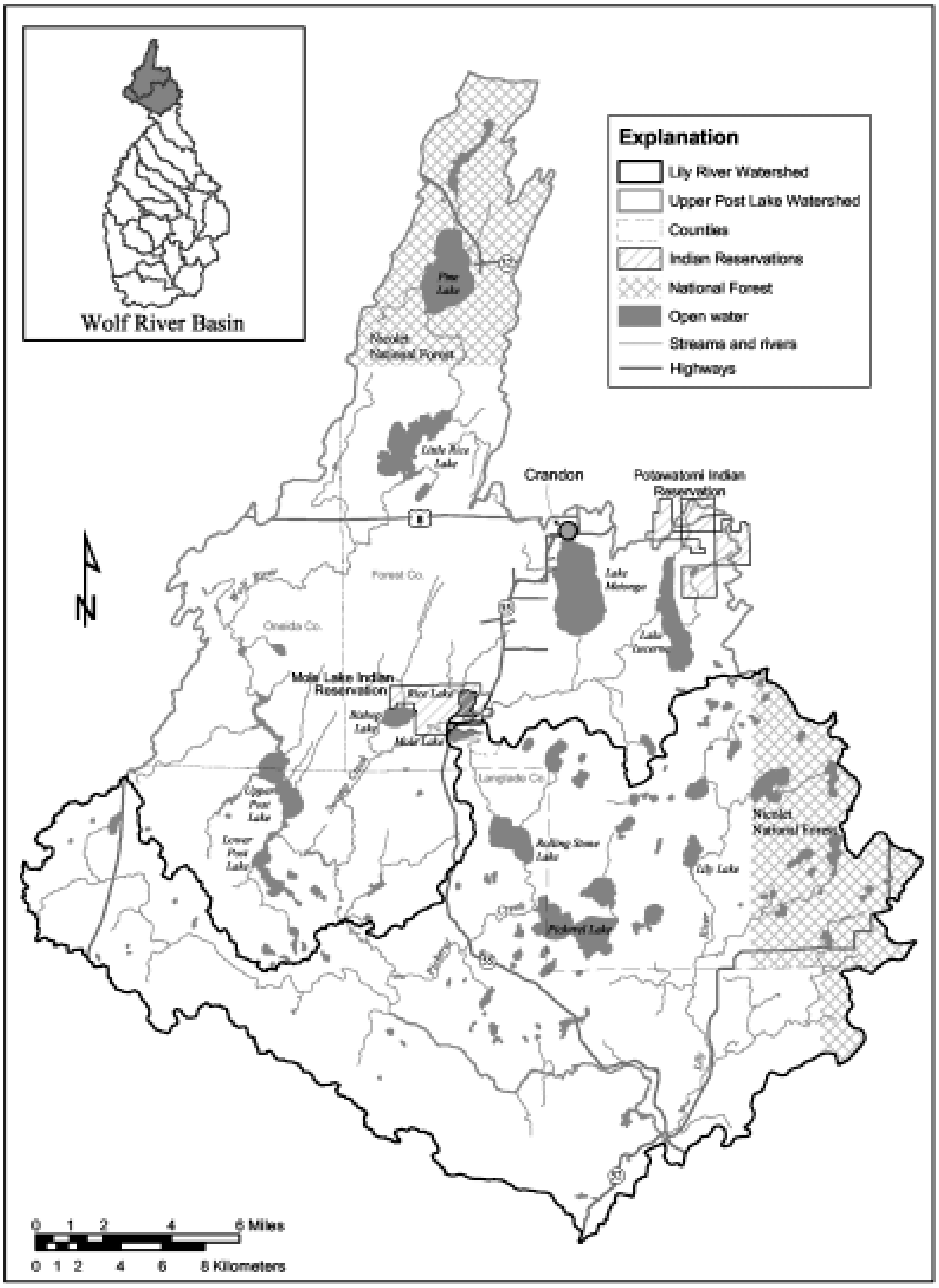


Figure 3. Location of Pickerel Creek in the Lily River Watershed.

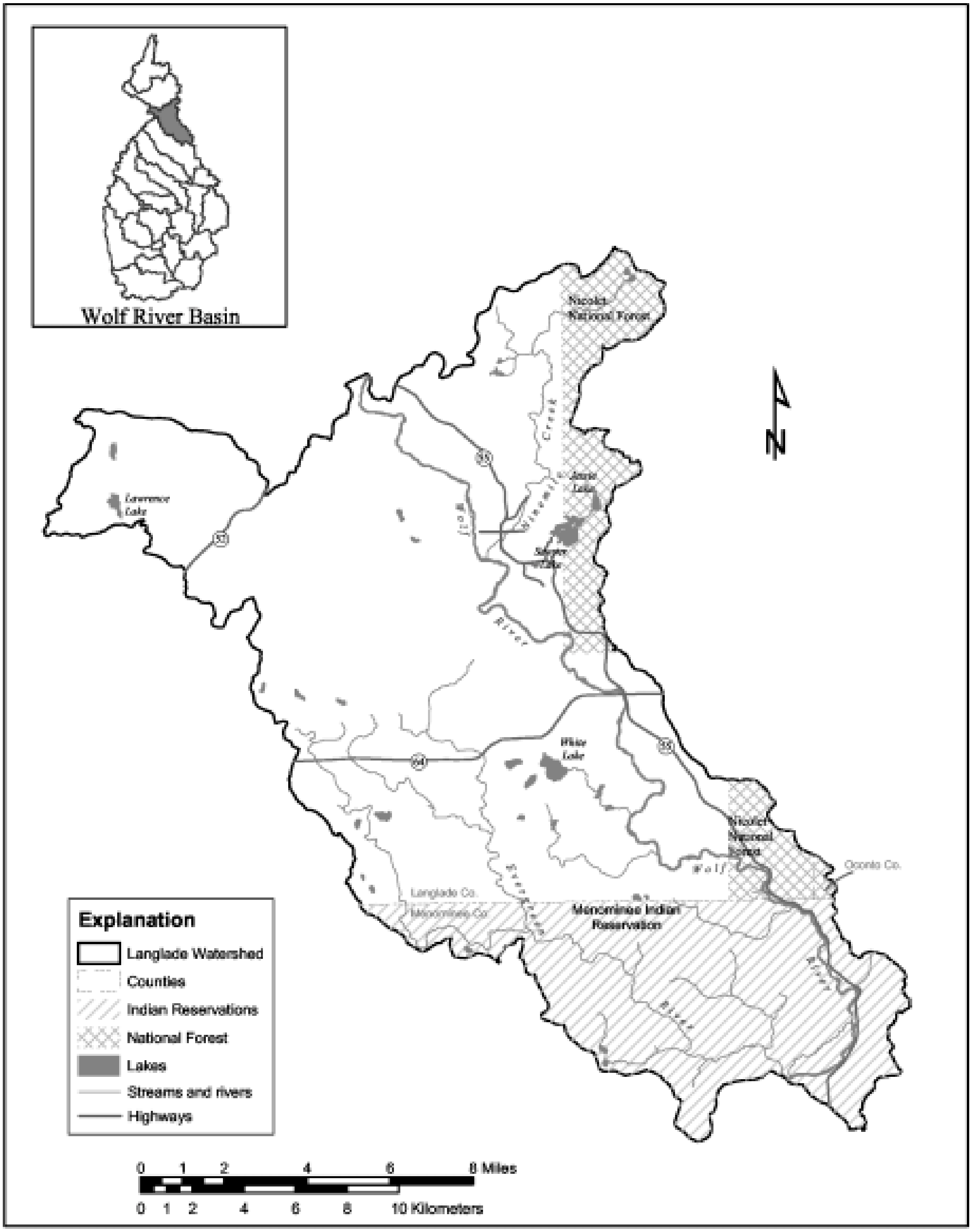
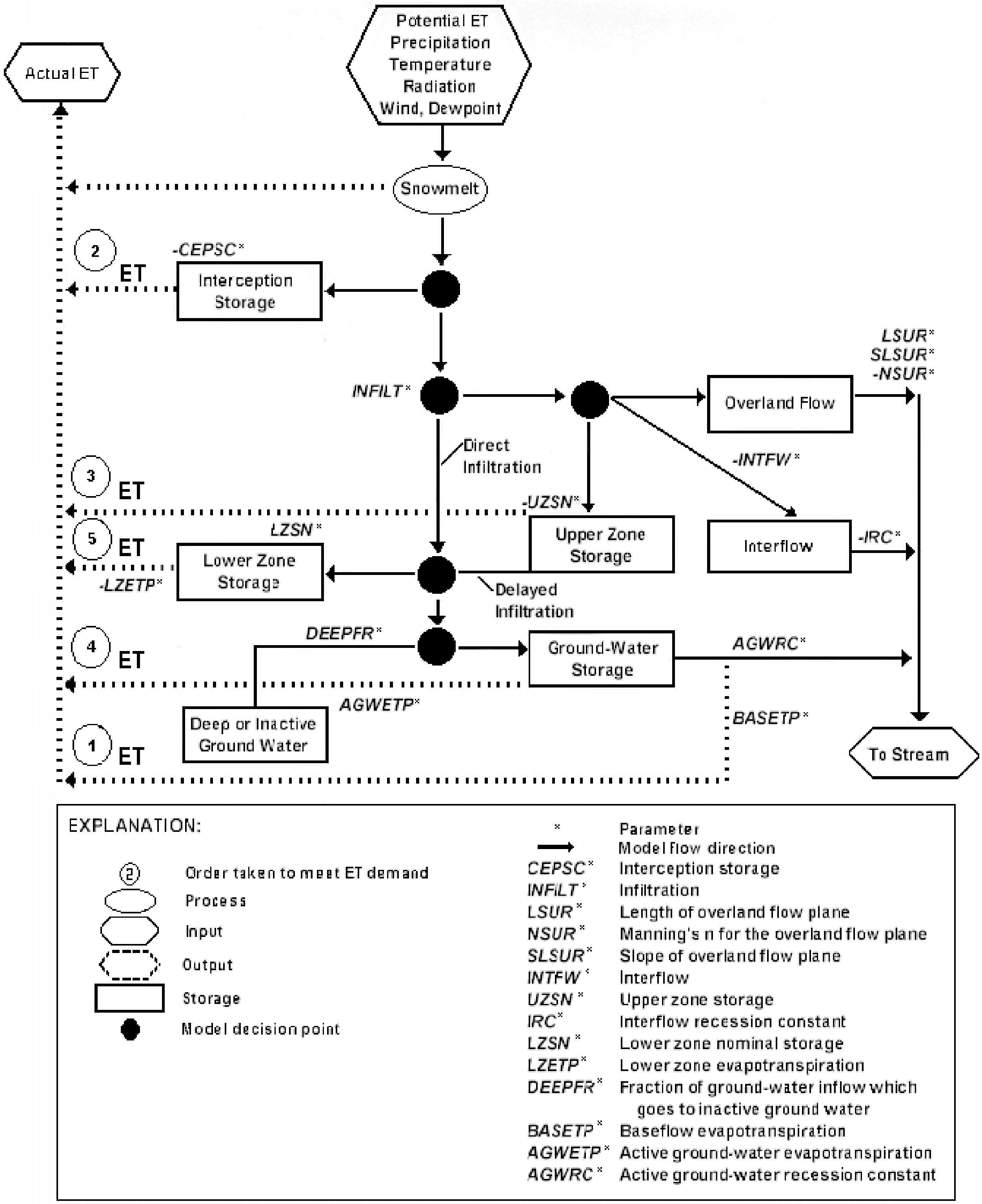


Figure 4. Wolf River/Langlade and Evergreen Rivers Watershed.

FIGURE 5. Schematic diagram of the Hydrological Simulation Program - Fortran model.



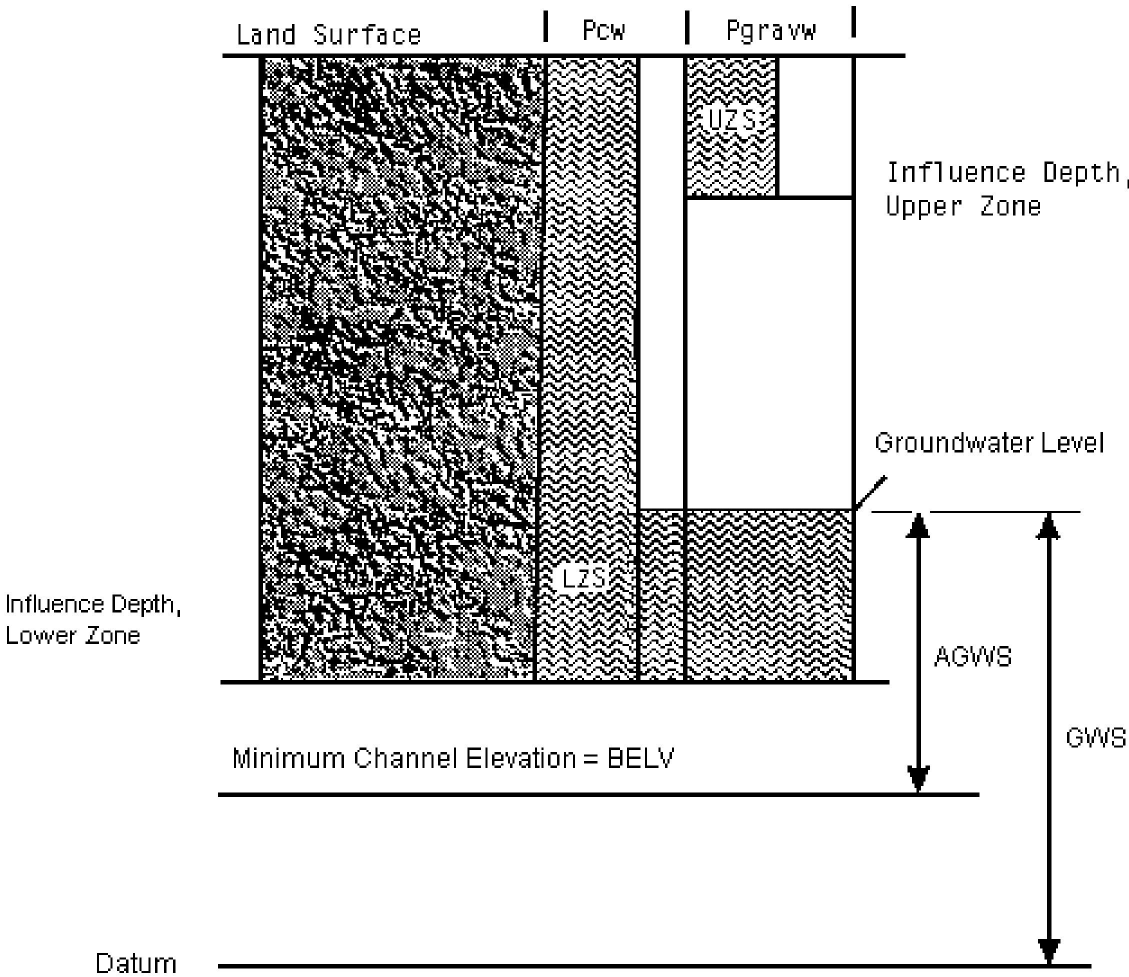


Figure 6. Sketch of Soil Moisture in the Unsaturated Zone

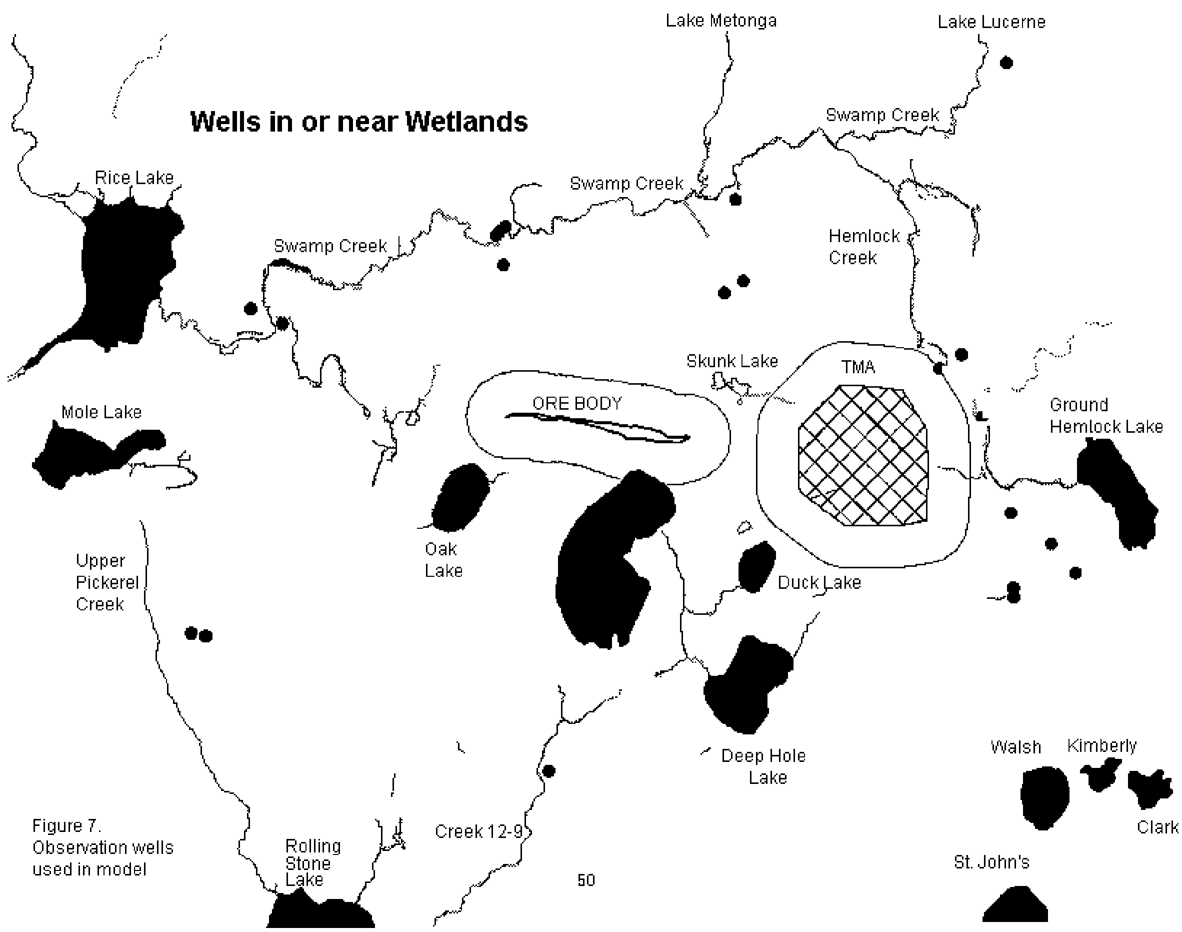


Figure 7. Observation wells used in model

Application of HSPF to the Upper Wolf River Basin for Evaluation of Hydrological Impacts of Crandon Mine

Simulation Plan

USGS Contract No. 1434-HQ-96-CN-30316
Delivery Order No. 10

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CONTENTS

FIGURES AND TABLES

SECTION 1

INTRODUCTION

1.1 Background And Objectives

A model of portions of the Upper Wolf River Watershed in northern Wisconsin is being developed for the purpose of predicting the impacts of a proposed underground copper/zinc mine (Crandon Mine) on the hydrology of the area. The site of the proposed mine is in Forest County Wisconsin, an area that consists largely of forests, wetlands, and lakes. The watersheds of Swamp and Pickerel Creeks (Figure 1.1), which are two of the headwaters of the Wolf River (a State Outstanding Natural Resource) contain the site, and Swamp Creek flows past the site and into Rice Lake on the Mole Lake Indian Reservation. Rice Lake holds a large stand of wild rice, which is dependent on a limited range of flow velocities and pristine water for successful growth. The specific purpose of the model is to evaluate the effects associated with mine construction, operation, and closure conditions on creek streamflows, wetland water levels, and lake water levels in the vicinity, and downstream, of the mine. In addition, the variables calculated by the model will be used to evaluate potential impacts to the aquatic habitat and ecology of the area, and regional impacts on the Upper Wolf River Watershed. The model is being developed using the U.S. EPA Hydrological Simulation Program - FORTRAN (HSPF) (Bicknell et al., 1997). This watershed modeling effort is being coordinated with a separate groundwater modeling effort (USACE, 1997) by the U.S. Army Corps of Engineers, which focuses on groundwater impacts. The FEMWATER groundwater modeling code is being used in that effort.

This document is the simulation plan for developing the Swamp/Pickerel Creeks Watershed hydrology model and a regional model of the Upper Wolf River, using HSPF. It identifies and describes the watershed characteristics and types of data required/available for the model, and briefly presents our intended approach for constructing and calibrating the model. As this model is developed, application details may have to be modified based on the availability and quality of the data, unforeseen issues, and complications that may become evident only during the calibration effort. This Simulation Plan is an overall guide to ensure that the project team is aware of the general modeling approach, assumptions, and issues. As with any plan, it will be adjusted and modified throughout the application effort and will ultimately evolve into the final project report as the technical details, data, and modeling results are developed. The major steps in the simulation process consist of:

1. collection and development of time series data
2. characterization and segmentation of the watershed
3. calibration and verification of the model

These three major simulation steps will be discussed in detail in the following sections of this simulation plan. Section 2 describes hydrologic and meteorologic data needed for the simulation, Section 3 discusses other types of data needed to characterize the watershed, Section 4 describes the calibration/verification process and the preliminary analysis of the simulation period for the Swamp Creek Watershed, and Section 5 contains a brief review of other issues, including alternative scenarios, development of the regional model of the Upper Wolf Basin, and the project schedule.

Climatological and streamflow stations near the proposed Crandon mine.

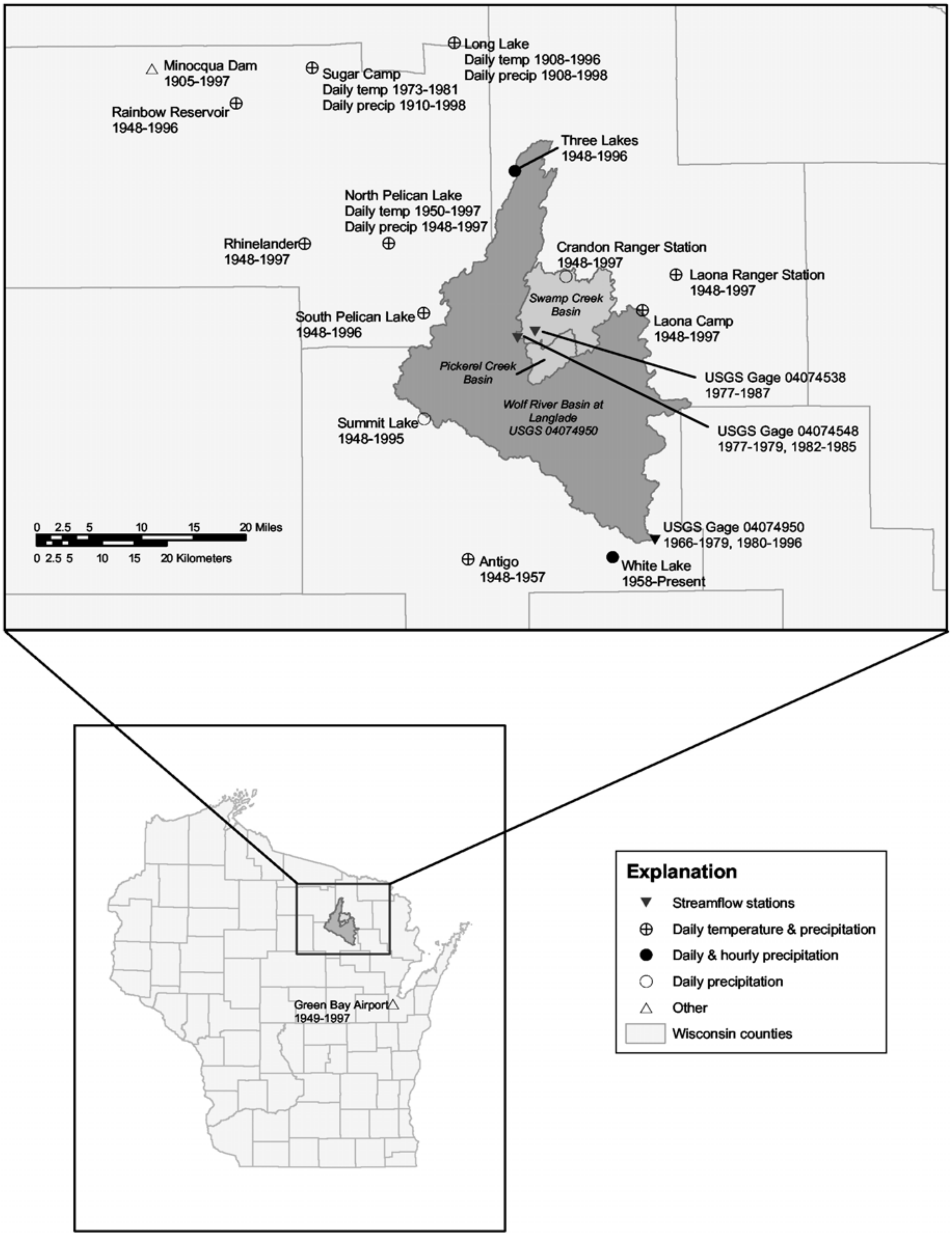


Figure 1.1 Map of Swamp/Pickerel Creeks and Upper Wolf River Watersheds

SECTION 2

HYDROLOGIC AND METEOROLOGIC DATA

HSPF requires time series data as input to the model, and for comparison with simulation results. The types of data needed for a particular application depend on the scope of the simulation (*i.e.*, the options and processes being simulated) and any unique aspects of the watershed or reason for modeling the watershed. Simulation of hydrology generally requires continuous **rainfall** and **evaporation** as inputs, and observed **streamflow** for comparison with model predictions (calibration). In northern areas like upper Wisconsin, where snow accumulation and melt have a major impact on the flow regime, additional meteorologic data are needed as input to the snow sub-model. These data are **air temperature, dewpoint temperature, solar radiation, cloud cover**, and **wind speed**. Observed **snow depths** are needed if calibration of the snowmelt processes is to be performed. Finally, in the Swamp Creek/Upper Wolf River Basins, the model is being designed primarily to assess impacts on **water levels in the lakes and wetlands** in the vicinity of the proposed Crandon Mine, and possibly to use new methods in HSPF that require **groundwater levels**. Therefore, these types of data are needed for comparison with model results. In summary, the following time series data types are necessary for the Swamp/Pickerel Creek and Upper Wolf River HSPF Models:

Data Type	Time Resolution	Units
precipitation	1 hour	inches
potential evapotranspiration	1 day	inches
air temperature	1 hour	deg F
dewpoint temperature	1 day	deg F
wind movement	1 day	miles
cloud cover	1 day	tenths
solar radiation	1 hour	Langleys
streamflow	1 day	cfs
lake levels	1 month	ft
snow depth	1 day	in, ft
groundwater levels	1 month	ft

2.1 Precipitation

Ten rainfall stations have been identified that are within the vicinity of the Swamp Creek and Upper Wolf River Basins, and which may be useful in the modeling effort. These stations and their periods of record are listed in Table 2.1. (These stations and the other meteorologic data stations being considered for use in the model are shown on the map in Figure 1.1). Of the precipitation stations, the Laona, North and South Pelican Lakes, Summit Lake, and Three Lakes stations are expected to provide the most useful data. The Crandon station has many missing periods, and the other stations are located further away. The Minocqua Dam station is apparently a good quality, long term record, which may be useful for long term simulations.

TABLE 2.1 PRECIPITATION STATIONS

Station Name	Time Interval	Period of record
Three Lakes	day, hour	1948-1996
Summit Lake Ranger Stn.	day	1948-1995
Laona 6 SW	day	1948-1997
N. Pelican Lake	day	1948-1997
S. Pelican Lake	day	1948-1996
Crandon Ranger Stn.	day	1948-1997
Minocqua Dam	day	1905-1997
Rainbow Reservoir	day	1948-1996
Antigo 1 SSW	day	1948-1997
White Lake	day, hour	1958-1996

These stations will be utilized differently for the two watersheds due to the relative sizes of the watersheds and the geographical distributions of the stations. For larger watersheds, such as the Upper Wolf River Basin, where multiple stations are located within or near the basin, the stations are assigned to one or more model segments based on Thiessen polygons or a similar areal analysis. This necessitates correcting all of the stations (*i.e.*, filling in the missing data), and distributing the daily records to an hourly time interval (see description below). Because of the relatively small size of Swamp/Pickerel Creek Watershed, and the location of all of the observed rainfall stations outside the watershed, the recommended method in this situation is to use a group of stations closest to the watershed to develop a single composite record for input to the model. The possible methods for combining the stations include simple arithmetic averaging, Thiessen polygon weighting, and inverse-distance-squared weighting.

In order to produce the most accurate simulation of the water balance, HSPF requires short time interval (*i.e.*, at least hourly) rainfall inputs. Therefore, the precipitation data records should be dis-aggregated to an hourly time step. This is accomplished by imposing the hourly distribution of a nearby hourly station on each day's rainfall total. Typically, this is done on a one-day basis, in which each day's distribution is obtained from the hourly station having a daily total closest to the daily station's value. Since only two hourly stations (Three Lakes and White Lake) are currently available to provide this distribution for Swamp Creek, either another method will have to be used for days that are missing or otherwise unavailable from these two stations, or additional hourly stations will be required to complete this task.

2.2 Potential Evapotranspiration

HSPF requires input of a time series of potential evapotranspiration (PET) on a daily basis. Typically, measured pan evaporation is used along with a "pan coefficient" to derive an estimate of lake evaporation, which is assumed to be the potential evapotranspiration. The relationship is:

PET = pan coefficient * pan evaporation.

The simulated or “actual” evapotranspiration is computed by HSPF based upon the model algorithms, ET parameters, and the input PET time series. Long term data indicate the pan coefficient for this part of Wisconsin is approximately 0.78 (Env. Data Service, 1979).

Pan evaporation data are available at Minocqua Dam, which is approximately 50 miles from the study area. Two other stations located in northern Wisconsin are Marshfield (85 miles) and Green Bay Airport (75 miles). Since pan evaporation data are less variable than rainfall, a watershed of this size requires only one record. Therefore, the closest available station (Minocqua Dam) will be used for the model.

In areas where icing occurs, pan evaporation is generally measured from approximately May through October. Although this is the period when most evaporation occurs, the model requires data for the entire year. Therefore, data for the missing winters (and other missing periods) must be estimated. Candidate procedures for estimating evaporation include the Penman equation, the Hamon method, or the Meyer method.

2.3 Other Meteorologic Data

Simulation of snow accumulation and melt requires five meteorologic data types in addition to rainfall and PET. These are air temperature, dewpoint temperature, wind speed, cloud cover, and solar radiation. Also, measurements of the snow depth are needed if the snow simulation is to be calibrated by comparison with observed data. Generally, max-min daily air temperature data are used to develop an hourly record by imposition of a diurnal curve through the maximum and minimum. Daily dewpoint temperatures can be estimated from the minimum air temperature, or computed from relative humidity data. If cloud cover or percent sunshine data are available, these data can be used to generate daily solar radiation, which should be distributed to hourly values for input to the model.

Table 2.2 lists the primary stations that will provide these data types. With the exception of air temperature and snow depth, which are available near the study area (*i.e.*, Laona), and dewpoint temperature, which can be estimated as noted above, the other variables are available from more distant stations. The weather station at Minocqua Dam, which is 50 miles away, is the primary source of cloud cover and radiation (computed from the cloud cover). The nearest wind speed stations that have been located are Eau Claire Airport and Green Bay Airport. If further analysis of these data sets show that they are poor quality or have significant periods of missing values, other stations (such as Minneapolis) may be required to complete the data record, especially for the long term simulations.

2.4 Streamflow and Lake Levels

Measured streamflow data are compared with simulated streamflow to calibrate the model. Therefore, accurate, long term flow records are needed for calibration. The three USGS surface water stations available on the streams in the study area are shown in Table 2.3.

TABLE 2.2 OTHER METEOROLOGIC DATA STATIONS

Data Type	Station Name	Period of Record
Air Temperature		
	Laona 6 SW *	1948-1997
	Minocqua Dam	1905-1997
	Rainbow Reservoir	1948-1996
	N. Pelican Lake	1950-1997
	Antigo	1948-1997
	Long Lake	1948-1996
Dewpoint Temperature		
	Green Bay AP	1949-1997
	Laona * (est'd from min temp)	1948-1996
Cloud Cover		
	Minocqua Dam *	1978-1995
Solar Radiation		
	Minocqua Dam * (est'd from cloud cover)	1978-1995
	Eau Claire AP	1951-1997
Wind Speed		
	Eau Claire AP *	1949-1997
	Green Bay AP	1949-1997
Snow Depth		
	Sugar Camp * (near Laona)	1948-1997
	Long Lake	1948-1995
	Minocqua Dam	1948-1997
* - Primary station for modeling		

Hydrologic calibration and verification of the Swamp Creek Watershed can be performed using data at the two Swamp Creek stations above and below Rice Lake. Since the time periods of these stations overlap for most of the record, and they are very close together, a correlation between the stations has been developed in order to estimate the missing periods in each record. This results in nine years of data at the station above Rice Lake for the primary calibration and verification of the watershed. This station encompasses flow from most of the impact area for the proposed mine, and is representative of the remaining impact area in the Pickerel Creek drainage. The nine years of data at the station below the Rice Lake will be used to ensure the Rice Lake flows and water levels are correctly represented. The station at Langlade contains 28 years of data for calibration and verification of the Upper Wolf River Regional Model.

TABLE 2.3 STREAMFLOW STATIONS

Station Name	Station Number	Period of Record
Swamp Creek above Rice Lake	04074538	8/77 - 9/83, 10/84 - 12/86
Swamp Creek below Rice Lake	04074548	8/77 - 9/79, 4/82 - 6/85
Wolf River at Langlade	04074950	4/66 - 9/79, 10/80 - 9/95

Two key issues to be addressed in this study are: 1) how well can the HSPF-based model predict lake and wetland water levels and stream flow and velocities, and 2) how will operation of the proposed mine impact these parameters. In addition, the predicted impacts on stream flows and water levels in both lakes and wetlands will provide the basis for evaluating potential habitat impacts. Therefore, measured lake levels (in addition to the stream flows described above) are necessary for comparison with simulated values, and use of the high water table version of PERLND to model the wetland portion of the watershed, requires wetland water levels (*i.e.*, groundwater levels within the wetlands) for comparison with simulated values. Limited groundwater well data and lake level data (both of unknown extent and frequency) are currently being processed. Lake levels are available at the following locations:

Deep Hole Lake	Rolling Stone Lake	Hoffman Spring
Duck Lake	Rice Lake	St. John's Lake
Little Sand Lake	Skunk Lake	Walsh Lake
Oak Lake	Ground Hemlock Lake	

2.5 Construction of the WDM File

The WDM file is the repository for time series data associated with the model application. During simulations, HSPF obtains time series input data from the WDM file, and writes output time series to the file. A WDM file contains multiple time series records known as data sets. WDM files are created, maintained, and manipulated using several utility programs, such as ANNIE, METCMP, IOWDM, and SWSTAT.

The time series data for Swamp Creek and the Upper Wolf River Basin are currently being processed at the USGS District office in Madison, WI, with assistance from the USGS District office in Urbana, IL. This procedure includes reformatting the data to WDM format, filling any missing periods with data from nearby stations (or other estimation methods), development of a composite rainfall record for the Swamp Creek Watershed, and creation of hourly records of rainfall, solar radiation, and air temperature for input to the model.

SECTION 3

SEGMENTATION AND CHARACTERIZATION OF THE SWAMP CREEK WATERSHED

3.1 Segmentation Issues

The primary purpose of segmenting the watershed is to divide the study area into individual land segments that are assumed to produce a homogeneous hydrologic and water quality response. The segmentation then allows the user to assign identical model parameter values to all parts of the watershed that produce the same unit response of runoff for a uniform set of meteorologic conditions. Where the weather patterns vary across a watershed, it is necessary to also divide the land segments by meteorological characteristics to accurately reflect the spatial meteorologic variability and its effect on the hydrology and water quality of the watershed. However, for a watershed the size of the Swamp Creek, the meteorologic variability is usually small, and limited to short term rainfall variations, which cannot be detected by the available rainfall gage density.

Another purpose for segmentation is to produce model output at various locations within the watershed so that questions can be answered about these locations. Finer segmentation facilitates the process of isolating specific areas of the watershed and compiling model results applicable to the areas.

For the Swamp Creek Watershed, the segmentation is based on: 1) sub-watershed boundaries, *i.e.*, the lakes and streams tributary to the main creeks, and 2) the stream channel geometry (impacted by lakes and beaver dams). The segments were also selected in order to isolate the various lakes and areas that will be impacted by the proposed mine. Additional changes to the segmentation may be warranted in order to coordinate the model with the FEMWATER model that is being developed by the U.S. Army Corps of Engineers. The current segmentation is shown in Figure 3.1 and the segments are listed in Table 3.1.

3.2 Land Use and Land Cover

Land use affects the hydrologic response of a watershed by influencing infiltration, surface runoff, and water losses from evaporation or transpiration by vegetation. The movement of water through the system, and subsequent erosion and chemical transport, are all affected significantly by the vegetation (*i.e.*, forest, grasses, and crops).

The primary data source for land use in the study area is the “WISCLAND Land Cover Data” set. The initial summary of land uses in the area identified the 26 subcategories within 10 major categories listed in Table 3.2, and shown on a map of the study area in Figure 3.2. In addition, a separate coverage (Type I-IV) divides wetland areas within much of the study area into four categories, primarily distinguishing areas of groundwater recharge from groundwater discharge.

HSPF Segmentation

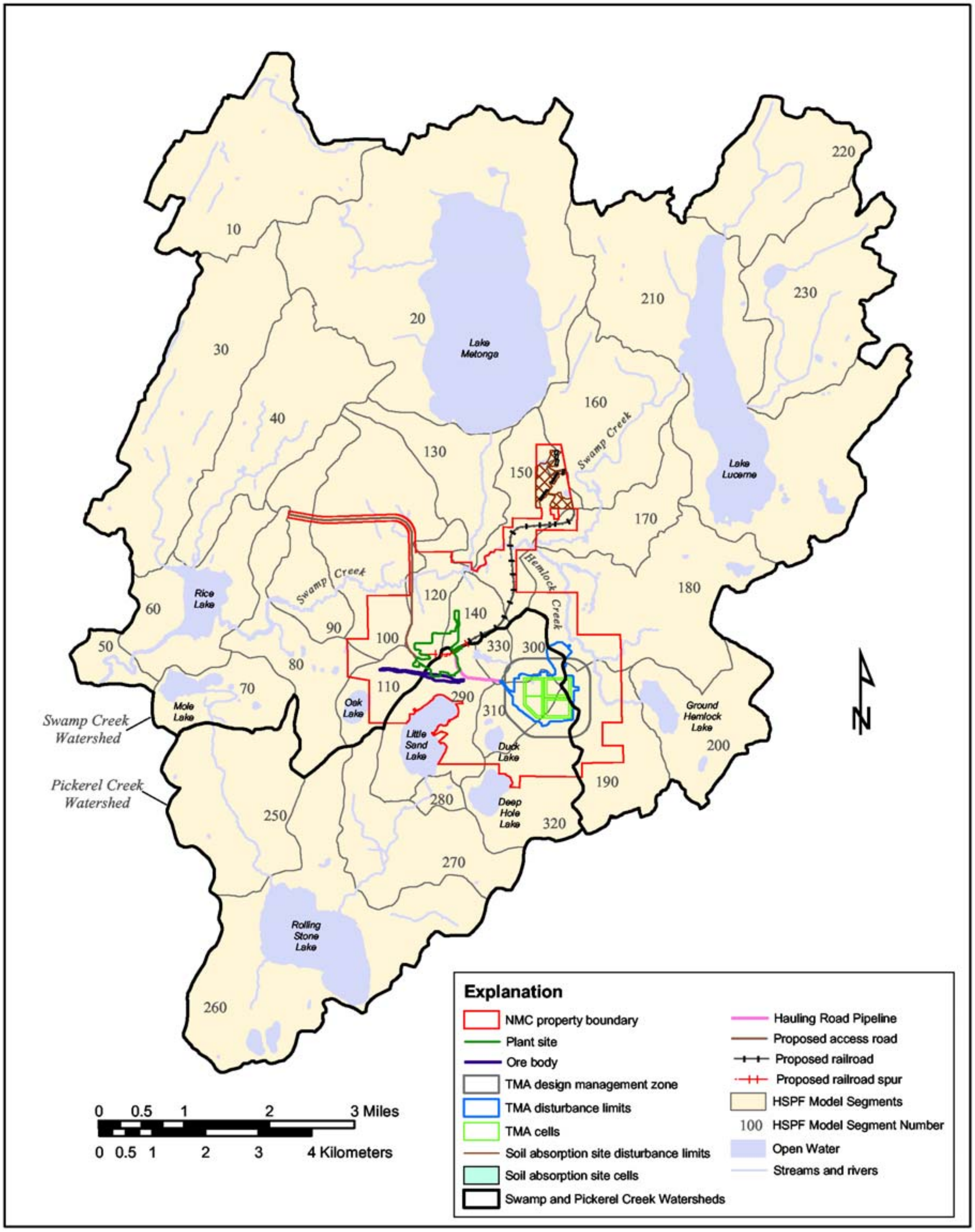


Figure 3.1 Swamp/Pickerel Creek Watershed Model Segments.

TABLE 3.1 SWAMP/PICKEREL CREEK WATERSHED SEGMENTATION

Segment No.	Description	Area (ac)
S10	Upper portion of Lake Metonga watershed	2123
S20	Lower portion of Lake Metonga watershed (USGS 04074510)	6117
S30	Unnamed trib to Rice Lake (USGS 04074535)	2512
S40	Gliske Creek (USGS 04074543)	1830
S50	Swamp Creek below Rice Lake at County M (USGS 04074548)	270
S60	Rice Lake (USGS 04074545)	1259
S70	Mole Lake (USGS 04074546)	729
S80	Swamp Creek above Rice Lake including Hoffman Springs (USGS 04074538)	1078
S90	Swamp Creek between Rice Lake and Outlet Creek (USGS 04074528) (Lower portion)	852
S100	Swamp Creek between Rice Lake & Outlet Creek (Middle portion)	1744
S110	Oak Lake (USGS 04074532)	425
S120	Swamp Creek between Rice Lake and Outlet Creek (USGS 04074524) (Upper portion)	474
S130	Outlet Creek	848
S140	Newly discovered tributary to Swamp Creek	282
S150	Swamp Creek u.s. of Outlet Creek and d.s of Hemlock Creek (USGS 04074508)	876
S160	Swamp Creek below Lake Lucerne (USGS 04074505)	1575
S170	Swamp Creek u.s. of Hemlock Creek (USGS 040745065)	763
S180	Hemlock Creek (lower half) (USGS 040745076)	2189
S190	Hemlock Creek below Ground Hemlock Lake	1054
S200	Ground Hemlock Lake (USGS 04074507)	1111
S210	Lake Lucerne (USGS 04074501)	4812
S220	Unnamed tributary to Lake Lucerne (USGS 04074500	1382
S230	Unnamed tributary near Lake Lucerne	1868
S250	Unnamed tributary to Rolling Stone Lake - northwest side (USGS 04074654)	1651
S260	Rolling Stone Lake (USGS 04074656)	3464
S270	Unnamed tributary to Rolling Stone Lake - northeast side (USGS 04074653)	1341
S280	Below Little Sand and above beaver dam	131
S290	Little Sand Lake	1021
S300	Burr Oak Swamp	252
S310	Duck Lake (USGS 040746507)	392
S320	Deep Hole Lake (USGS 040746503)	1039
S330	Skunk Lake (USGS 040746501)	132

TABLE 3.2 WISCLAND LAND COVER CATEGORIES IN THE SWAMP/PICKEREL CREEK AREA

Category	Subcategory	% of Watershed	
URBAN			1.09
	High intensity urban	0.18	
	Low intensity urban	0.91	
CROPLAND			3.44
	Other row crops	< 0.01	
	Forage crops	3.44	
	Cranberry bogs	< 0.001	
GRASSLAND			3.53
	Grassland	3.53	
CONIFEROUS FOREST			2.25
	Jack pine	0.01	
	Red pine	1.24	
	White spruce	0.29	
	Mixed coniferous forest	0.71	
DECIDUOUS FOREST			58.56
	Aspen	10.37	
	Red oak	0.01	
	Sugar maple	7.43	
	Mixed deciduous forest	38.50	
MIXED DECIDUOUS/CONIFEROUS FOREST			8.37
	Mixed deciduous/coniferous forest	8.37	
WATER			9.69
	Open water	9.69	
WETLAND			14.19
	Emergent wet meadow	0.73	
	Shrubby wetland - mixed	1.00	
	Shrubby wetland - broadleaf deciduous	1.80	
	Shrubby wetland - broadleaf evergreen	0.63	
	Shrubby wetland - coniferous	0.29	
	Forested wetland - deciduous	1.54	
	Forested wetland - coniferous	7.35	
	Forested wetland - mixed	0.85	
BARREN			1.08
	Barren	1.08	
OTHER			0.05
	Shrubland	0.05	

HSPF Segmentation with WISCLAND Satellite-derived Land Cover, Wetland Types and Wetland Land Cover

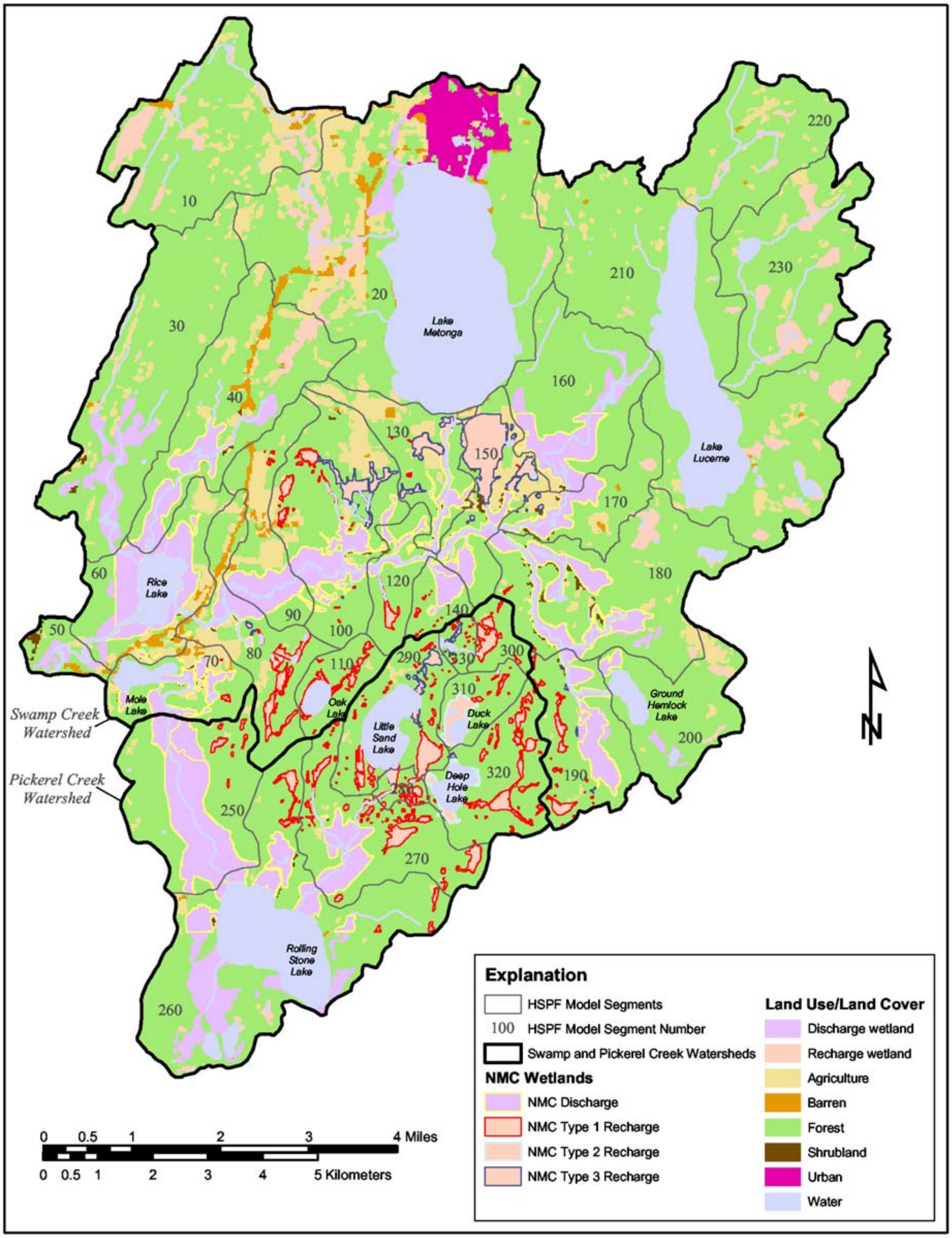


Figure 3.2 - 3.4 Study area land use/land cover with wetland types.

Examination of the Land Cover data indicates the dominant land uses/covers are forest (64%), wetland (17%), cropland/pasture (7%), and residential/urban (1%). The forest areas are mostly deciduous and mixed, with a small amount of coniferous. In Swamp Creek, the forest is mostly mixed, and in Pickerel Creek, the forest is mostly deciduous. A single forest category is sufficient for the model, with seasonal adjustments to interception parameters to account for variations in deciduous and mixed forest covers over the area. If significant clear-cut areas are located in the basin, this may have to be changed. There is sufficient cropland and grassland area to warrant an explicit “Ag/pasture” category in the model.

Wetlands significantly impact the overall hydrology of the study area, and warrant separate land categories. There are two wetlands coverages available for the watershed. The Wetland Land Cover coverage (Figure 3.3) differentiates wetland areas based on vegetation, while the Wetland Types (Figure 3.4) coverage is based on the relative elevations of the wetland and the water table, and the permeability of the underlying geologic material (these categories are discussed further below). Unfortunately, the two coverages are not the same, *i.e.*, there are areas in each coverage that are not included in the other coverage. The Land Cover wetland areas are mostly forested, with a small amount of non-forested wetland near Rice Lake. The separation of recharge and discharge wetlands in the Wetland Types coverage provides a more significant hydrological basis for multiple wetland categories. Therefore, tentatively, three wetland categories are planned for the model. All of the area for Wetland Types I - III will be defined as “recharge wetland” and the Type IV areas as “discharge wetland.” Any Land Cover areas not included in the Wetland Types coverage will be categorized as “wetland.”

Portions of the town of Crandon drain to Metonga Lake, and are contained within one model segment. Inclusion of a separate urban/residential category is warranted for this segment, and may possibly be split into pervious and impervious areas (*i.e.*, modeled as a PERLND and an IMPLND). In “construction” and “mine operation” scenarios, this urban category could be used to represent portions of the plant site.

The tentative model categories are listed below. Table 3.3 shows the breakdown of these land uses by model segment. Also shown in Table 3.3 are open water areas (mostly lakes) and a small amount of “shrubbery” and “barren” areas, both of which can be included in the forest category.

Forest	Land Cover “forest” categories
Agriculture/pasture	Land Cover “cropland” and “grassland” categories
Urban	Land Cover “urban” categories
Recharge wetland	Type I - III wetland areas
Discharge wetland	Type IV wetland areas
Other Wetland	“Land Cover” wetlands not covered by Wetland Types areas

Figure 3.3 wetland types map has been combined with Figure 3.2 (page 13).

Figure 3.4 wetland land cover map has been combined with Figure 3.2 (page 13).

TABLE 3.3 LAND USE

Segment	Urban acres	Ag/pas acres	Forest acres	Water acres	Wetland acres	Rechrg acres	Dischrg acres	Barren acres	Shrub acres	Total acres
10		284	1,556	6	232	0	0	44	0	2,123
20	498	669	2,434	2,008	347	0	0	161	0	6,117
30		133	2,083	3	282	0	0	2	9	2,512
40		157	1,219	1	139	0	254	58	2	1,830
50		17	175	0	52	0	0	14	12	270
60		165	383	70	210	0	371	60	0	1,259
70		100	352	66	20	4	166	21	0	729
80		147	665	0	19	83	116	47	0	1,078
90		195	421	0	12	3	189	32	0	852
100		226	1,039	0	54	123	292	9	1	1,744
110		7	326	44	9	38	0	0	0	425
120		0	334	0	36	17	87	0	0	474
130		181	452	0	74	54	77	10	0	848
140		0	181	0	25	3	73	0	0	282
150		166	292	0	132	240	45	0	0	876
160		38	1,333	10	193	0	0	0	0	1,575
170		73	548	0	134	4	0	5	0	763
180		81	1,616	8	443	42	0	0	0	2,189
190		7	779	0	208	50	10	0	0	1,054
200		66	886	83	50	0	27	0	0	1,111
210		183	3,466	1,012	140	0	0	11	0	4,812
220		70	1,267	0	42	0	0	3	0	1,382
230		71	1,581	26	189	0	0	0	0	1,868
250		20	963	0	99	8	560	0	0	1,651
260		27	2,003	701	420	38	272	3	0	3,464
270		10	977	0	27	111	217	0	0	1,341
280		0	77	1	14	39	0	0	0	131
290		20	612	220	27	132	0	10	0	1,021
300		3	196	0	4	49	0	0	0	252
310		0	290	22	7	73	0	0	0	392
320		0	782	91	32	135	0	0	0	1,039
330		0	108	0	12	11	0	0	0	132
SUM	498	3,116	29,397	4,373	3,683	1,257	2,756	490	23	45,595
% of Basin	1.1%	6.8%	64.5%	9.6%	8.1%	2.8%	6.0%	1.1%	0.0%	100.0%

It is expected that land use has been relatively stable in the study area in recent years, since the area is largely forest, wetland, and water. However, as noted above, if it is determined that significant clear-cutting has occurred in the watershed during the simulation period (in particular, during the calibration/verification periods), impacts of this change may have to be included in the model.

Simulation of Wetlands

Since wetlands cover approximately 17% of the model area (Swamp and Pickerel Creek), and have a significant impact on the hydrology, the method of simulating them in the model is an area of importance. As discussed in Section above, two coverages are available for the wetland areas. The Wetland Types coverage distinguishes wetlands by the relative depths of the water table and the wetland surface, and whether the wetland is recharging the groundwater or discharging from it. The four categories are briefly defined as follows:

- **Discharge.** The water table is essentially the same as the wetland surface, and water is discharging from the groundwater to an adjacent stream. The underlying material is variable.

- **Recharge type I.** The wetland is "perched" above the water table (*i.e.*, the bottom of the wetland is above the water table), and the underlying soil has low permeability. Water is slowly recharging the groundwater.

- **Recharge type II.** The wetland is underlain by low permeability material, and is not connected to the water table beneath it. However, it is adjacent to a lake, which is connected to (and recharging) the groundwater. Wetland water level is controlled by the water level of the lake.

- **Recharge type III.** The water table and the wetland surface are essentially the same, and therefore, the wetland is directly connected to and recharging the groundwater beneath it.

Because of the importance of wetlands in controlling the water levels and streamflows in the study area, the "wetland/water table" version of the hydrologic module of HSPF called PWATER will be used. In the "standard" or prior version of the PWATER module (*i.e.*, prior to HSPF Version 12), the soil is represented through a series of storages: surface detention, interflow, upper zone, lower zone and active groundwater. HSPF does not normally define exact locations for these storages, and only some have maximum capacities associated with them. Some of the standard assumptions of PWATER are:

- The active groundwater storage represents shallow aquifers that provide base flow to the rivers. The groundwater outflow in HSPF is a function of the entire active groundwater storage; deep or 'inactive' groundwater is not represented except as a sink for deep recharge.

- The active groundwater storage is assumed to lie deep enough, so that it does not interact with the unsaturated zone.

- The unsaturated zone is modeled with two storages: lower zone and upper zone. There is no percolation from the lower zone to active groundwater. Both storages have nominal capacities that provide a measure of the saturation of the storages. These storages are not affected by the active groundwater.

- The interflow storage represents water that reaches the stream channel through a subsurface path. There is no maximum capacity associated with this storage. It is assumed that the storage can grow as necessary to accept the inflow.

- Surface runoff is driven by ground surface slope. It is assumed that water stored on the surface will run off fast enough so that evaporation from the surface storage is negligible.

Many of these assumptions are not valid in wetland areas. In these environments the saturated zone interacts with, and can take over the unsaturated zone. Often the groundwater reaches the surface and the land is submerged for long periods. Wetlands are typically flat, and surface runoff is not driven by differences in ground elevation. Water stored on the surface is subject to evaporation.

Therefore, in order to represent the wetland areas, PWATER was modified in a recent study (SFWMD, 1996) to keep track of the groundwater levels (saturated zone elevation) and to model the interaction between the saturated zone and the unsaturated zone. In this version, the "groundwater" can rise through the original unsaturated zone (lower and upper layers) and inundate the surface, where it is subject to evaporation and surface runoff. However, surface runoff is a function of storage (water level) instead of slope. In this version, groundwater discharges to the stream whenever the groundwater level is above a user-defined base elevation (BELV) that generally represents the bottom of a nearby stream channel.

While the wetland version of PWATER is not able to represent all of the details of the Wetland Types categories, it most likely can be adapted to most of the area covered by these categories. In the discharge wetland, which is the predominant type (6% of total area and 70% of Wetland Types I-IV area), BELV will be defined as the bottom of the adjacent stream channel, and the varying groundwater elevation (GWEL) will generally be above it, resulting in discharge to the stream.

The recharge categories are more difficult. For recharge Types I and III, BELV can be defined at or near the surface. Since the groundwater elevation is at the surface (*i.e.*, GWEL will be very close to BELV), the outflow to the stream will be either zero or small; and part of the outflow will be routed to the deep/inactive groundwater, thereby representing recharge. The Type II category is a case that is not capable of being represented by PERLND, because of the direct interaction with the adjacent water body (lake). This interaction violates the HSPF principle against upstream transfers. A possible solution for the Type II wetlands is to include their areas within the area of the adjacent lake, and subtract them from the land area. This should not affect the model results significantly, because of the small area of Type II wetlands and the fact they are primarily located in just three segments (290, 310, 320).

The method for simulating the wetland areas not included in the Wetland Types coverage will be addressed after more information is obtained about these areas. Possibly, they can be allocated to the Wetland Types, such that wetlands adjacent to a stream channel will be "discharge" wetlands, and the others will be assumed to be "recharge" wetlands. Alternatively they could be simulated using the standard PWATER method (*i.e.*, not as a wetland). Available elevation data will be critical in determining how best to represent these areas.

3.3 Soils and Surface Physiography

Soils have a large influence on basin discharge behavior because their properties determine the rates of infiltration, and interflow, which in turn affect the timing of surface runoff. Variability of soils characteristics within a watershed can produce different hydrologic responses from different parts of the watershed. When available, soils data for the study area will be reviewed from the standpoints of variability and determination of parameter values for individual model segments.

The watershed is an uplands area with crystalline bedrock overlain by unconsolidated glacial deposits. The most recent glaciation resulted in formation of a "hummocky" surface with lakes and wetlands within the surface depressions. A DEM or slope coverage of the watershed will be analyzed to obtain average slopes by land segment and land cover type.

3.4 Water Body and Wetland Characterization

Impacts on the water bodies and wetlands within the Swamp and Pickerel Creeks watersheds are the major issues to be addressed by this study. As such, it is important to accurately characterize the physical properties of the stream, lake, and wetland systems in the HSPF model of the watershed. The stream reach segmentation requires consideration of stream bed slope, entry points of major tributaries, and relative locations of lake and wetlands. In the Swamp and Pickerel Creeks, the task of characterizing some of the reaches (both longitudinal and cross-sectional) will be difficult due to the large amount of lake and channel area surrounded by wetlands.

Each segment (see Table 3.1) in the model will contain at least one channel reach (representing a stream or lake) that receives the discharge from the tributary area (*i.e.*, the land in the segment). Individual reaches are represented in HSPF using function tables (FTABLEs). An FTABLE is a table of stage-volume-discharge information that allows HSPF to determine the amount of channel storage and the routing of streamflow through the reach system. In addition to stage (depth) and discharge information, the FTABLE also includes surface area and channel volume. Therefore, it is important to have information on the stream channel cross-section geometry and channel slope and bottom roughness. Stage, discharge, area, and volume information are required at approximately 0.5 or 1.0 foot levels for the stream channel within its banks. Since it is difficult to collect this information for the entire channel and floodplain, approximations are generally needed to extend the cross-sections to include the flood plain. Channel bottom and flood plain roughness can be estimated from representative photographs of the channel, showing the surrounding environment.

For "lake" segments, the depth-discharge relationship can be estimated as the flow over a weir, and the lake volume can be estimated from average depth and surface area, or preferably obtained from more detailed lake bathymetry data, when available. Therefore, the ideal location on the outlet stream for measuring the cross section is the controlling point (weir). The flow depths over the weir must be correlated with the lake elevation, depth, and volume information in order to complete the FTABLE.

3.5 UCI File

The HSPF User's Control Input (UCI) file contains all of the input to HSPF except the time series data, which is contained in the WDM file(s). The UCI file contains the options, parameters, watershed characterization data, and information to control the interaction with the WDM file (*i.e.*, the data sets for input and output time series data). The following is a brief outline of the contents of a UCI file for simulation of hydrology in the Swamp/Pickerel Creek Watershed:

GLOBAL block	Title and time span of the run
OPN Sequence block	List of model operations (land & stream segments) in order of simulation
PERLND block	Option flags and parameters defining pervious land segments
RCHRES block	Option flags and parameters defining river segments (reaches)
FTABLES block	Tables defining volume vs. discharge relationship for the reaches
EXT SOURCES block	Specification of input (met) time series from WDM file
EXT TARGETS block	Specification of output time series to WDM file
SCHEMATIC block	Connectivity of the watershed segments and areas of land segments
MASS-LINK block	Specification of material (water) transfers between watershed segments

SECTION 4

CALIBRATION AND VERIFICATION

4.1 Calibration Time Period

A review of all of the time series data needed for hydrologic calibration (rainfall, evaporation, observed flow, and additional met data) indicates that long term simulations are possible. The calibration/verification period on Swamp Creek, using the two USGS streamflow stations above and below Rice lake, is limited to the nine year period (1978 - 1986). The missing periods in these records have been filled in by correlating the two records. If all of the other data are satisfactory, this supports a five year calibration period and four year verification period. Since it would be better if the calibration period included as much lake and groundwater level data as possible, we have tentatively assigned the 1982-1986 period to the calibration, and the 1978-1981 period to verification.

The local precipitation and evaporation (Minocqua Dam) records apparently support simulations from about 1950 through 1996, and the other met data from Minocqua Dam cover 1978-1995. Therefore, the longest simulation period without use of a more distant station for met data, is 1978-1995/6, or approximately 18 years. Extending the simulation period, and required input data, will likely be needed for scenario runs (see Section 5.1).

The USGS flow data for the Wolf River at Langlade will support a longer calibration and verification period. Since the flow record extends from 1966 through 1995, the currently available data would allow a simulation period of 1978-1995, and if additional meteorologic data are obtained, it could be extended back to 1966.

4.2 Initial Calibration Parameters

Selection of <u>initial</u> calibration parameter values for the snow and conventional hydrology portions of HSPF will be derived primarily from previous HSPF simulations, performed by USGS and AQUA TERRA personnel, in Wisconsin, Minnesota, and other nearby states. Relatively little experience exists with the wetland hydrology algorithms, but a recent application in Florida will be used to guide development of the initial values.

HSPF Section PWATER parameters represent the watershed's surface and subsurface hydrologic variables throughout the simulation period. They are the controls that govern the pathways and storages available to the precipitation in transit to becoming either streamflow or evaporation. Of the 17 standard PWATER parameters, two will vary monthly as set by the user. These parameters are interception storage (CEPSC) and soil lower zone evapotranspiration (LZETP). By varying these parameter values on a monthly schedule we can represent the growth of the crop canopy and deciduous forest changes, water uptake from the soil column and plant transpiration, and subsequent crop harvest.

4.3 Calibration Procedures and Comparisons

Calibration of HSPF to represent the hydrology of the Swamp Creek Watershed is an iterative trial-and-error process. Simulated results are compared with recorded data to see how well the simulation represents the hydrology observed in the watershed. By iteratively changing specific calib-ration parameter values the simulation results are changed until a good comparison of simulated and recorded data is made. The standard HSPF hydrologic calibration is divided into four phases:

1. **Establish an annual water balance**. This consists of comparing the total annual simulated and observed flow (in inches), and is governed primarily by the input meteorologic data (rainfall and evaporation) and the parameters LZSN (lower zone nominal storage), LZETP (lower zone ET index), and INFILT (infiltration rate).

2. **Adjust low flow/high flow distribution**. This is generally done by adjusting the groundwater or baseflow, because it is the easiest to identify in low flow periods. Comparisons of mean daily flow are utilized, and the primary parameters involved are INFILT, AGWRC (groundwater recession), and BASETP (baseflow ET index).

3. **Adjust stormflow/hydrograph shape.** The stormflow, which is compared in the form of daily and short time step (1 hour) hydrographs, is largely composed of surface runoff and interflow. Adjustments are made with the UZSN (upper zone storage), INTFW (interflow parameter), IRC (interflow recession), and the overland flow parameters (LSUR, NSUR, and SLSUR). INFILT also can be used for minor adjustments.

4. **Make seasonal adjustments.** Differences in the simulated and observed total flow over summer and winter are compared to see if runoff needs to be shifted from one season to another. These adjustments are generally performed by using seasonal (monthly variable) values for the parameters CEPSC and LZETP. Adjustments to KVARY and BASETP are also used.

The procedures and parameter adjustments involved in these phases are more completely described in Donigian et al. (1984), and the HSPF hydrologic calibration expert system (HSPEXP) (Lumb et al., 1994). HSPEXP produces a standard set of mass balance, statistical, and hydrograph comparisons that greatly facilitate calibration. It also provides advice on parameter adjustments and enforces various error criteria (user-defined) for deciding whether each phase of calibration is satisfactory. HSPEXP will be used in the calibration of the Swamp Creek Watershed.

For wetland portions of the watershed that are modeled using the wetland version of PERLND, the calibration also includes comparison of simulated and observed groundwater levels in these PERLNDs. As described in Section 2, both groundwater elevations and lake elevation levels, which have been recorded at 10-11 lakes in the area, will likely be compared to simulated wetland water levels. In addition to the standard PERLND parameters, the main variables for calibrating these levels include the soil porosities (PCW, PGW, UPGW) and the base elevation for groundwater outflow (BELV), which corresponds to the bottom of nearby channels or the “bottom” of the wetland, depending on the type of wetland.

4.4 Verification

Verification is an evaluation of the final calibration parameter values using a second meteorologic time period different from that used in calibration. The evaluation is done using the final calibration with a new period of record and then evaluating how well the simulated results match the recorded information for this new time period. A poor verification may result in need for re-calibration of the watershed with additional data.

Verification of the simulation follows conclusion of the simulation evaluation. Verification is dependent on the availability of additional hydrometeorological times series data beyond that used for the calibration period. As described above in Section 4.1, there are sufficient data available to support a total of nine years of calibration/verification on Swamp Creek within the period 1978-1986. Therefore we are recommending a four year verification period from 1978-1981.

In addition to the above verification "in time," a second type of verification will be completed "in space." After determining hydrological parameters on the Swamp Creek Watershed by calibrating (primarily) to the streamflow records near Rice Lake, the parameter set will be applied to simulation of the Pickerel Creek Watershed, where no streamflow records are available. This verification will be evaluated by comparing simulated and observed lake levels in the watershed.

SECTION 5

OTHER ISSUES

5.1 Simulation and Analysis of Alternative Scenarios

The normal way of using HSPF to analyze alternative conditions, or scenarios, on a watershed is to define a BASELINE scenario, which is often the calibrated condition with the model run for the longest period of available meteorologic data. The output is then analyzed statistically for mean annual values (and variance statistics), and on a frequency basis to generate flow, or water level frequency curves (actually cumulative frequency) with the horizontal axis indicating the '% of time' or '% chance' the output variable (vertical axis) is exceeded. Model input, land use/cover parameters, and/or system components (*e.g.* stream reaches, network, lake outlets) are then modified to represent the change caused by a PROPOSED scenario, and the model is run again for the same extended time period. The model results for the scenario are analyzed in the same way and compared with the BASELINE results to identify the likely impacts of the PROPOSED scenario. Numerous alternative scenarios can be simulated and compared to both the BASELINE conditions and the other scenarios.

Since this analysis is based on a long period (up to 20, 30, or more years) of generated values, it includes essentially all potential climate and flow conditions on the watershed. As a result, this encompasses the wet, dry, and average conditions that are often used as a basis for scenario comparisons with less comprehensive approaches. Obviously, the frequency curve can be interpreted to define conditions associated with high, low, and mean or median flows (or water levels) as needed, but each condition is not run individually. In addition, the frequency curve indicates how often the conditions are expected to occur. In other, less comprehensive approaches, meteorologic data are analyzed to select specific years that are defined as wet, dry, and average, but there is no guarantee that these years will produce flow/runoff years that meet the same criteria used to select the meteorologic data. That is, rainfall frequency is not equal to flow/runoff frequency.

Scenarios

To evaluate the likely impacts of the Crandon Mine, four primary scenarios must be represented, with a few possible alternatives for the construction and operation phases. The four are defined as follows:

- BASELINE
- Mine Site/TMA CONSTRUCTION Phase
- Mine/TMA OPERATION Phase
- Closure/Post-closure Phase

Further detailed review of the mine operation and TMA design information is needed to develop appropriate model changes to represent the construction and operation phases, but we can initially define these four scenarios as follows:

BASELINE: This would be the calibrated condition run for the longest period of complete meteorologic input data, and would represent the 'current' condition of the watershed. This is essentially a 'natural' condition since there is very little development within the watershed

Mine Site/TMA CONSTRUCTION Phase:

This scenario would represent how the watershed would be expected to behave during the mine and TMA construction period. We will need coverages of the proposed construction areas and TMA to identify the model segments impacted by the construction activities, along with the actual acreages of the impacted land. In the model we will replace the land cover types from the Baseline scenario for the impacted areas with an open surface (denuded) condition, an impervious surface (*e.g*. for parking lots), and/or some other appropriate condition.

If dewatering is performed as part of the construction phase, we will need to know the pumping rates to represent this impact by extracting it from the groundwater storage. Also, this scenario could be run both with and without surface runoff (erosion and stormwater) control plans, depending on the final details and design of the plans.

Mine/TMA OPERATION Phase:

For the mine operation scenario, we will need to define the land surface conditions for this phase, and get the associated coverages. The areas involved should not be different than those used for the construction scenario, but the land surface conditions will change, and the surface runoff control plans may change. The pumping rate for the operation will be used to examine the associated change in groundwater levels.

Closure/Post-Closure Phase:

This scenario represents conditions on the areas impacted by the mine during and/or after closure activities and procedures have been implemented. Therefore, two alternatives may be assessed: conditions during the closure activities, and conditions following these activities. Clearly, the land conditions will be different than the BASELINE condition and they are likely to be some modification of the OPERATION scenario. If ongoing maintenance is required during the closure period, we will need to define these activities and their potential representation in the model runs.

If simulation of the Mine/TMA Operation Phase indicates that dewatering around the mine causes wetlands in the area to dry out, the storage parameters (e.g., the porosities and upper and lower zone nominal storages) for these PERLNDs could be modified in the Post-Closure Phase in an attempt to reflect the changes in water capacity caused by consolidation of the soils. However, in order to include this change in storage in the model, reliable information must be available in the literature on the magnitude of the change in storage that results from consolidation of the dewatered wetland. HSPF does not simulate the dewatering-consolidation process.

Scenario Results Analysis

The segmentation really defines the smallest spatial detail available from the model application for analysis of scenarios. Thus, the proposed HSPF segments shown earlier indicate where model output can be produced and analyzed. Each of these segments will include one stream or lake reach in the model, a number of pervious land segments (PLSs) for each land cover category discussed earlier (including wetlands), and possibly an impervious (ILS) segment if any impervious area is associated with the mine facilities or the town of Crandon.

For each PLS and ILS, a complete water balance on an annual, or total simulation period basis can be produced and analyzed, and for each RCHRES (stream or lake segment) storage, flow rate and depth are available. Therefore for each scenario, we can analyze the time series of flows from each stream reach, water levels for each lake that is represented in the model, and changes in the water balance components for each land category within each model segment (*e.g*. recharge wetlands, discharge wetlands, forests, TMA area for that scenario). Whenever possible, these variables will be compared with scenario results from the FEMWATER (USACE, 1997) model of the study area which is currently being developed. This comparison will require the segments described above to be compared (overlaid) to the FEMWATER model cells to determine their similarities in terms of areal size, level of detail, and other relationships.

At a minimum, we will analyze impacts at both the segment level (*i.e.*, outflows and PLS results) for the modified segments, and the downstream effects on nearby lakes, USGS gage sites, and possibly other sites. If additional output points are needed, we may need to review the segmentation to include more segments. The model segments associated with the mine facilities (290,300,310,140,150,180) and the stream/lake sites (Rice Lake, Mole Lake, Rolling Stone Lake, Skunk Lake and Swamp Creek above and below Rice Lake) can all be output with the latest segmentation.

The model output variables that can be analyzed in the current study include:

flow (cfs)
water surface elevation, (most appropriate for the wetlands and lakes)
water balance components (usually in inches), for each land cover category
flow velocity (fps), at each reach

In possible future efforts to include water quality variables, concentrations and loadings for sediment, nutrients, and other constituents can also be analyzed and evaluated in terms of the impacts of the alternative scenarios. In modeling of this type, so many numbers and information are generated, we must carefully select the specific points within the watershed, and the time scales to consider (hourly, daily, monthly, annual, frequency), in analyzing and evaluating model scenario results. Normally, daily values are analyzed (flows, depths, concentrations) to generate the frequency curves, but the variables can be analyzed on the other time steps as well.

5.2 Status of the Upper Wolf Basin Modeling

A regional model of the Upper Wolf River, which contains both the Swamp and Pickerel Creek Watersheds is currently planned as a larger scale comprehensive assessment. This regional assessment will supplement the Swamp/Pickerel Creek effort in a variety of ways. First, the longer period of flow records at the streamflow station at Langlade will allow calibration to a greater range of meteorologic and hydrologic conditions. Second, it will provide a larger scale verification of the parameter values developed at the smaller Swamp Creek Watershed. Finally, since the Upper Wolf drains the entire mine site area, it will serve to evaluate cumulative downstream impacts.

Development of the Upper Wolf River model is proceeding as a secondary priority to the Swamp/Pickerel Creek watershed efforts, and subject to allocation of budget resources. Since most of the meteorologic data needed for such a model will be derived from the same data used for the Swamp and Pickerel simulations, it is useful to discuss some of the issues related to these data.

Precipitation. Instead of using a single composite record of rainfall developed from multiple stations, the actual stations will be used directly, and each station will be used for a portion of the basin, depending on its location. Therefore, it is recommended that all available precipitation stations be corrected (missing periods filled in) and distributed to hourly records.

Evaporation. The Upper Wolf River Model will use the same record as the smaller basin model.

Streamflow. The USGS flow station at Langlade has data from 1966 through 1995.

Other Meteorology. The Upper Wolf River Model will use the same data as the smaller basin model. Therefore, if possible, data should be obtained for periods prior to 1978 during the Swamp Creek data development effort.

Segmentation. At the larger scale, model segments will be larger, with each segment generally encompassing the drainage of an entire creek. Stream channel segmentation will also be coarser, *e.g.*, only the larger lakes and streams will be explicitly represented. The main stem of the Upper Wolf River will be subdivided into main channel segments to receive the tributary inflows and allow impact evaluations at various locations down to the USGS Langlade flow station.

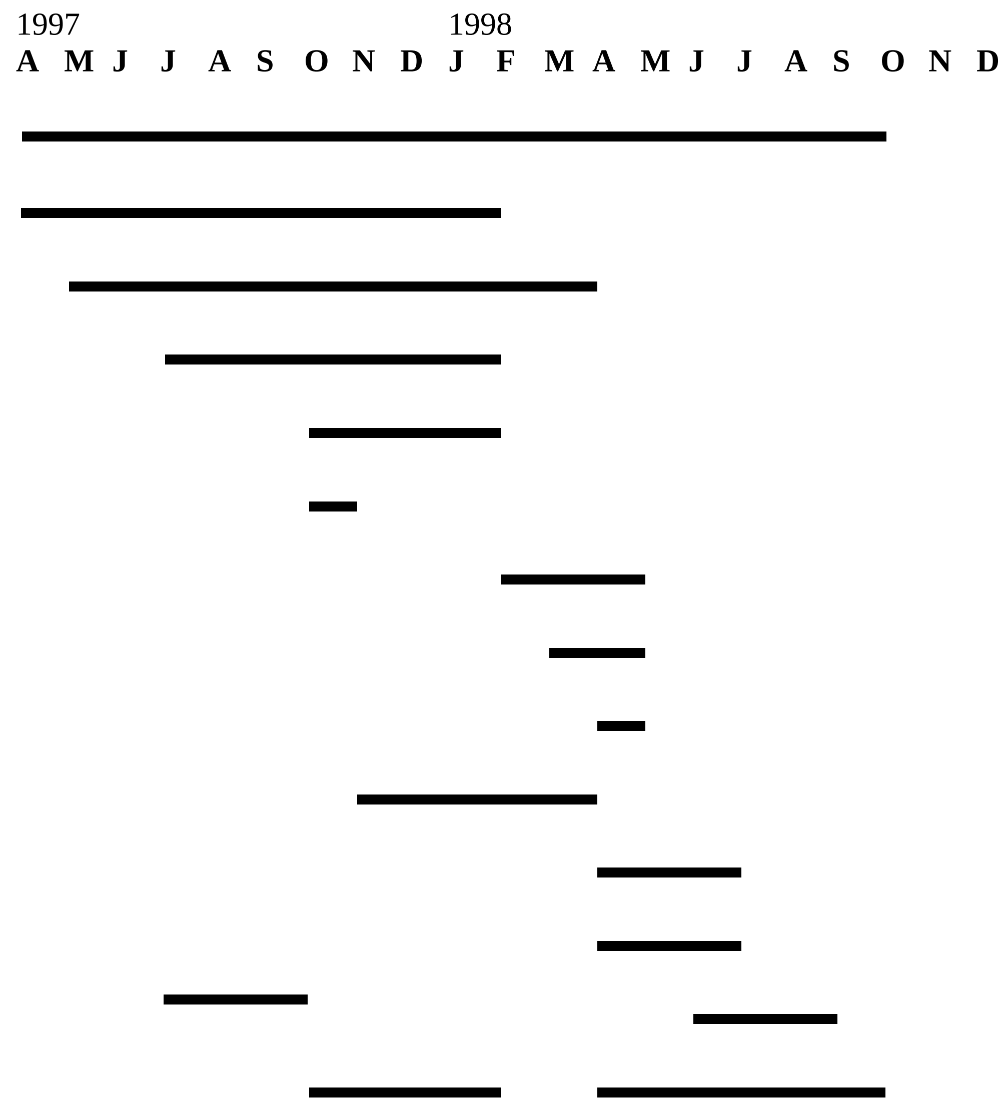
5.3 Project Schedule

Figure 5.1 shows the planned project schedule for the entire modeling effort, including the Swamp Creek, Pickerel Creek, and Upper Wolf River HSPF applications. The project schedule is expected to span an 18-month time period with initiation in April 1997 and completion in September 1998. Key milestones include the following:

Task	Estimated Completion
HSPF Hydrology Workshop	October 1997 (completed)
Simulation Plan and WDM Development	January 1998
Swamp Creek Hydrology Calibration & Verification	May 1998
Upper Wolf River Application	June 1998
Begin Scenario Simulations	June 1998
Scenario Simulation and Analysis	August 1998
Project Report	September 1998

Figure 5.1 Project Schedule

TASKS



1. Admin/Coordination/Communication
2. Simulation Plan Development/Data Review
3. WDM Development
4. Swamp Creek UCI Development
5. Swamp Creek Prelim. Calibration
6. HSPF Hydrology Workshop
7. Swamp Creek Final Hydrology Calibration
8. Swamp Cr. Sensitivity Analysis & Verification
9. Swamp Cr. Results Review
10. Pickerel Creek/Wolf River UCI Development
11. PC/WR Hydrology Calibration & Verification
12. Baseline and Scenario Definition & Parameterization
13. Scenario Simulation & Analysis
14. Report/Documentation Preparation

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